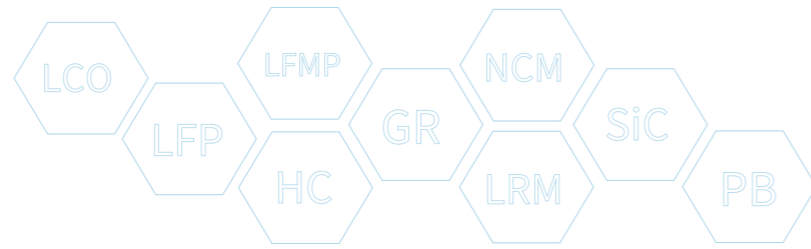


DEDICATED TO LITHIUM-ION BATTERY TESTING AND DEVELOPMENT



# INNOVATIVE LITHIUM ION BATTERY TESTING SOLUTION PROVIDER



# PRODUCT CATALOGUE >>>



Tel: 86-0592-5367060  
Mobile: 86-139-5954-7432

info@iesttech.com

4th Floor, No. 2,  
Xinfeng 2nd Road,  
Huli District, Xiamen City,  
Fujian Province, China

### IEST Major Business

- ◆ Special Testing Instruments
- ◆ Third-party Testing Service
- ◆ R&D Solutions



IEST LinkedIn

[www.iestbattery.com](http://www.iestbattery.com)

Initial Energy Science&Technology Co.,Ltd

# COMPANY INTRODUCTION ▶▶▶

Contents ◀

## Qualification

- National High-tech Enterprise
- Fujian Science and Technology Little Giant Enterprise
- Xiamen High-tech Enterprise
- Xiamen "Specialized and New" Enterprise
- Xiamen Science and Technology Enterprise
- Xiamen Key Listing Backup Enterprise
- ISO9001 Certification
- CE Certification



IEST is a high-tech enterprise focusing on the R&D and production of lithium-ion battery testing instruments, and is committed to providing leading testing solutions and services for the global new energy field.

IEST attaches great importance to the research and development of cutting-edge technologies. It has a multi-disciplinary research team covering the material science, physics, chemistry, electrochemistry, optics, machinery, electronics, computer science, artificial intelligence and so on. It has carried out independent research on the characterization methods, equipment technology, application solutions, etc., launched a number of industry-leading new instruments, obtained a number of invention patents and utility model patents, and served globally for the material enterprises, cell enterprises, terminal enterprises, scientific research institutes, universities and measuring department of governments. At the same time, IEST actively promotes the establishment of standardized and unified testing methods for both upstream and downstream enterprise, leads or participates in the formulation of national standards, industrial standards and group standards, and assists the innovation and development of the new energy industry!

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# Powder Resistivity & Compaction Density Measurement System



Scan QR code for the details



## A Differences between different models of PRCD series

| 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 LCO, NCM, etc.)   | Low resistance samples (such as LFP, graphite, conductive agent, etc.) | Positive and negative samples  | High resistance samples (such as LCO, NCM, etc.)                                  | Low resistance samples (such as LFP, graphite, conductive agent, etc.) | Positive and negative samples (Resistance Range 1μΩ~200MΩ)                       |
| Test Condition Range            | 1. Die diameter: 13mm;<br>2. Pressure: 70MPa;<br>3. Resistance range: 1μΩ~20MΩ<br>Remarks: National Standard for Graphite Negative Materials: GB/T 24533-2019, Stress Required 2200lb  |  |  | 1. Die diameter: 16mm;<br>2. Pressure: 200MPa;<br>3. Resistance range: 1μΩ~1200MΩ |  | 1. Die diameter: 16mm;<br>2. Pressure: 200MPa;<br>3. Resistance Range: 1μΩ~200MΩ |
| Testable Parameters             | <ul style="list-style-type: none"> <li>◆ Single point test</li> <li>◆ Continuous test</li> <li>◆ Variable pressure model</li> <li>◆ Pressure relief mode</li> <li>◆ Powder resistance, resistivity, conductivity, powder thickness, powder compaction density under constant pressure conditions</li> <li>◆ Powder resistance, resistivity, conductivity, powder thickness, powder compaction density under different pressure conditions</li> <li>◆ Relationship curve of powder resistance, resistivity, conductivity and powder compaction density</li> <li>◆ Automatic measurement software</li> </ul> |  |  |   |  |  |
| Mold diameter can be customized |  |  |  |   |  |  |

Note: IEST is committed to continuous improvement of our products. If there is a technical modification, we will not notify you otherwise! Thank you for understanding.

## B Instrument Principle - Resistance

**Test methods:** Place a certain powder (1~2g) into the jig, and put it into the PRCD1100 instrument chamber. Set the applied pressure ( $\leq 200\text{MPa}$ ) and holding time on the software. Start to test the changes of thickness and resistance of the powder during compression.

**Test parameters:** Stress, pressure, ambient temperature, ambient humidity, thickness, resistance, resistivity, conductivity, & compacted density.

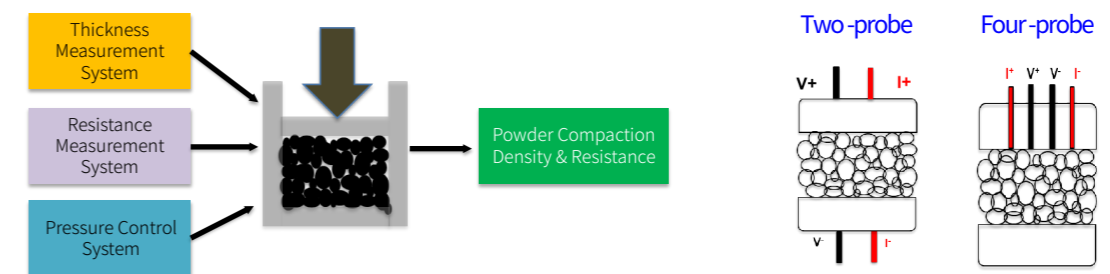
**Calculation formula**

$$\text{Compaction Density (g/cm}^3\text{): } D = \frac{m}{S \cdot L}$$

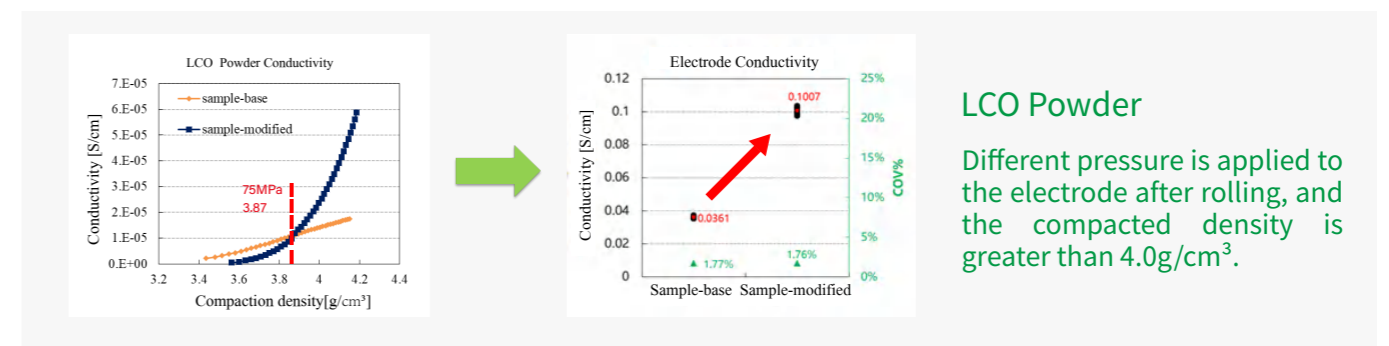
$$\text{Resistance (Ohm): } R = \rho \frac{l}{S}$$

$$\text{Conductivity (S/m): } \sigma_e = \frac{1}{\rho} = \frac{l}{RS}$$

$$\text{Resistivity (}\Omega \cdot \text{cm)-PRCD2100: } \rho = k \frac{U}{I} \quad (\text{Where } k \text{ is the thickness and diameter compensation coefficient)}$$



## C Why do we use high pressure for powder conductivity test?



**LCO Powder**  
Different pressure is applied to the electrode after rolling, and the compacted density is greater than  $4.0\text{g/cm}^3$ .

**Result analysis:**

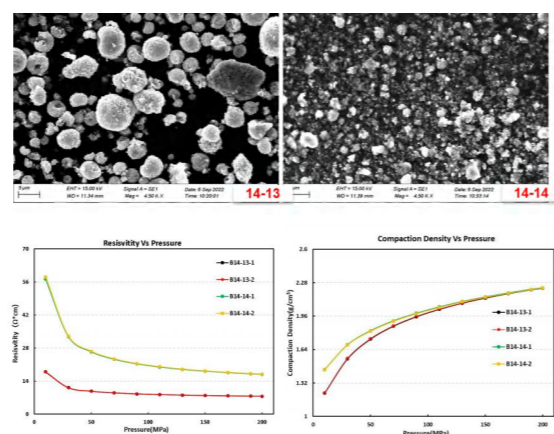
For modified powder samples, when the compaction is less than  $\sim 3.87\text{g/cm}^3$  (pressure  $< 75\text{MPa}$ ), the conductivity is lower than that before modification; however, when the compaction is greater than  $\sim 3.87\text{g/cm}^3$  (pressure  $> 75\text{MPa}$ ), the electrical conductivity of the modified powder is better than that before modification, and it increases rapidly with the increase of the pressure and the electrical conductivity performance is significantly improved;

In the powder conductivity test, the compacted density of the powder should be close to the compacted density of the actual electrode, so that the improvement of the powder conductivity in the real electrode can be effectively evaluated. Therefore, the test process needs to use a large pressure.

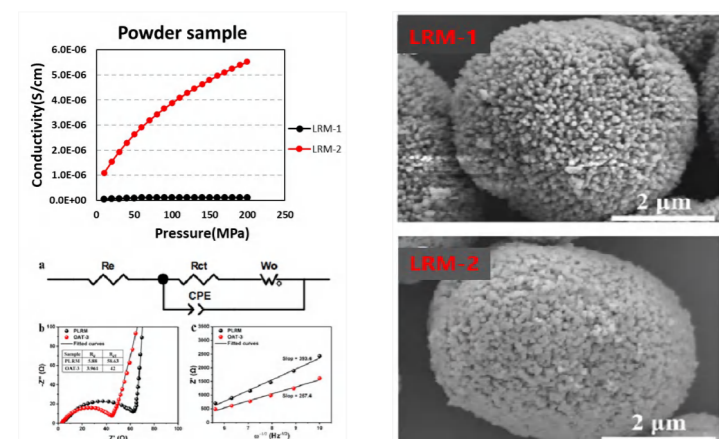
## D Application Case

### (1) Cathode material-LMFP

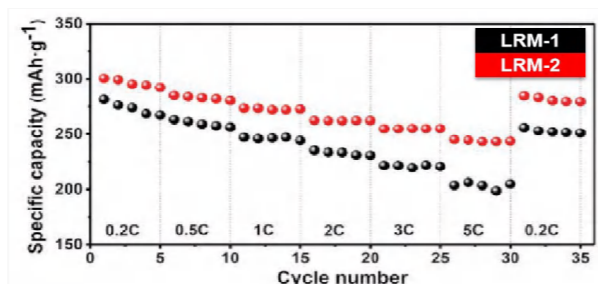
Comparing the conductivity, it shows that B14-13>B14-14. Combined with the SEM pictures, it can be found that the small particles of B14-13 materials are more fully filled with large particles during the entire compression process. Due to the overall porosity of B14-13 is relatively smaller, the contact between particles is better, and the conductivity better; In addition, although the compacted density of these two powders have little difference under high pressure conditions, the B14-13 has smaller compacted density under low pressure conditions. This is mainly due to the relatively poor flow and rearrangement effects of samples with a large particle size distribution range, so the porosity is relatively large and the compacted density is relatively small under low pressure.



### (2) Lithium-rich materials

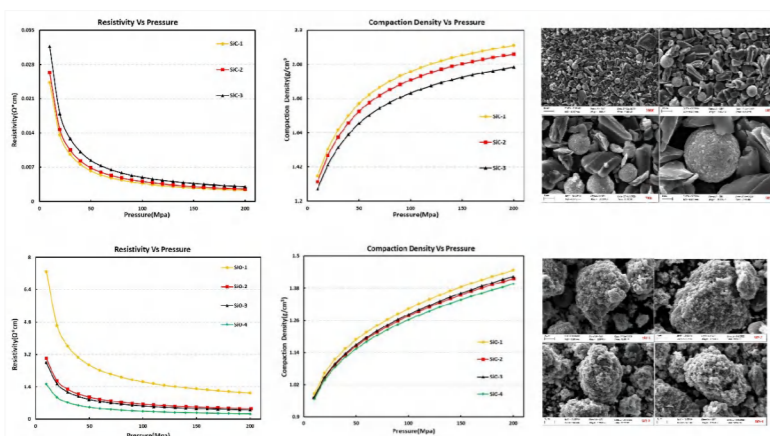


Analysis of the advantages and disadvantages of lithium-rich material with modification:  
The resistivity of the lithium-rich material can be reduced effectively by adjusting its surface structure.



W.B. Guo et al. Adv. Mater. 2021, 33, 2103173

### (3) Silicon-based materials

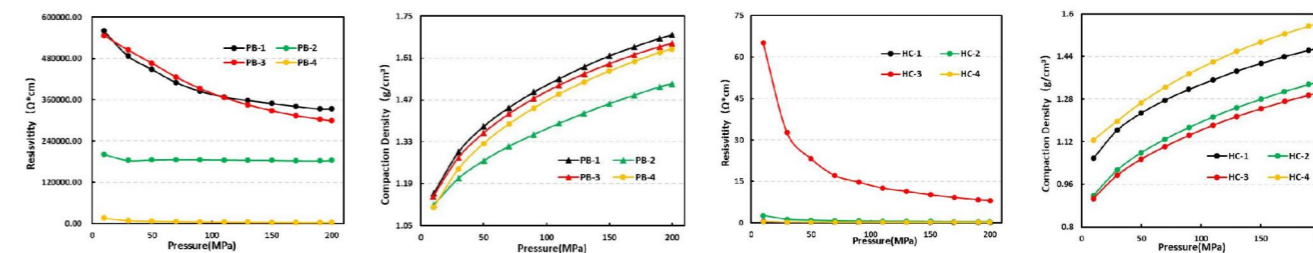


SiC-The Si content is 3%, 6% and 10%, respectively.

Evaluate the difference of materials under different mixing ratios and different modification processes, providing a new idea and direction for material modification, difference analysis and evaluation.

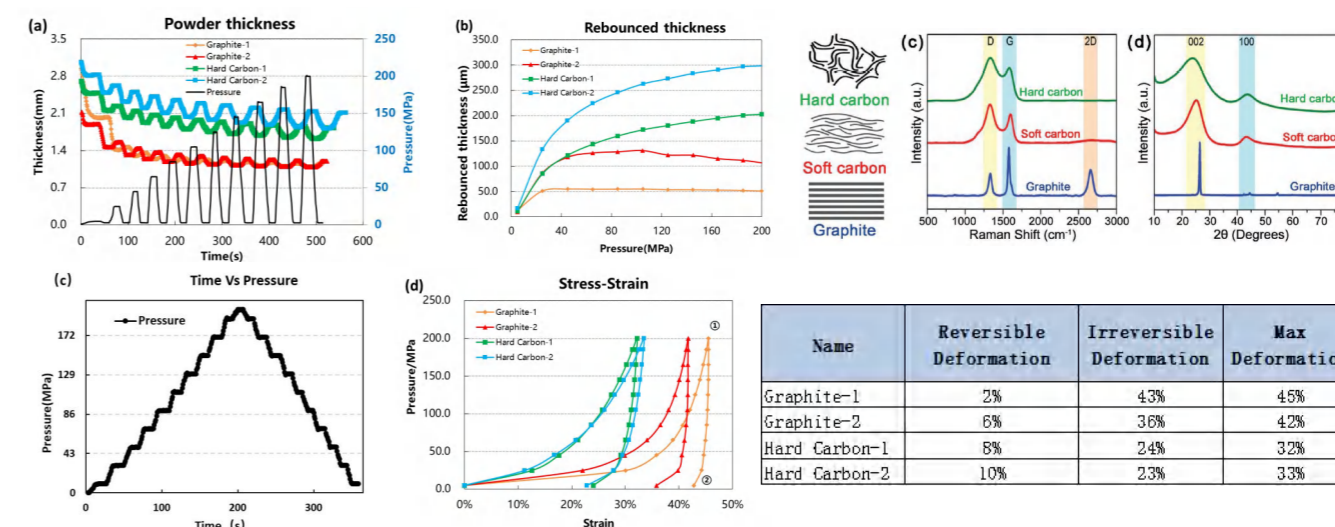
SiO-Material sintering temperature: SiO-1 < SiO-2 < SiO-3 < SiO-4

## (4) Positive and Negative Materials for Sodium ion battery



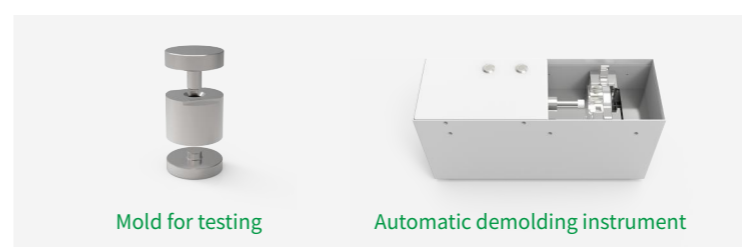
Conductivity evaluation of positive and negative powders for sodium ion batteries: Effectively evaluate the conductivity and compaction properties of Prussian blue and hard carbon under different modification conditions.

## (5) Compression properties of carbon materials



Analyzing material rebound force: the conductivity of graphite is greater than that of hard carbon, and the compressibility at the particle level is greater than that of hard carbon, which is mainly related to the microstructure of the two materials.

## E Powder Compaction Density Testing Mold



| Instrument Parameters (standard configuration)                    |                               |
|---|-------------------------------|
| Models  | Test pressurePCD-Device-13/16 |
| Die diameter (optional)   | 13mm/16mm                     |
| Test pressure   | ≤350MPa                       |
| Note: Mold size can be customized, mold material can be selected. |                               |

In order to solve the current problems during the compaction density testing, IEST designs and manufactures an alternative compaction density testing mold based on high strength and high wear-resistant materials and provides a demoulding system to protect the mold. At the same time, the service life of the mold is improved; in order to further meet the precise needs of users, IEST can also provide customized services for compaction density testing molds, which can be adapted to multi-party compaction density testing equipment, and solve your test exception problem in an all-round way!

# Single Particle Force Properties Test System



Scan QR code for the details

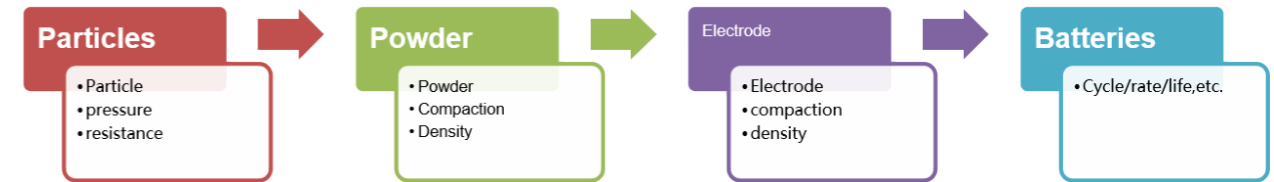


## A Model Comparison

| Device name                     | Single particle crush strength tester                    |          |
|---------------------------------|--|----------|
| Device model                    | SPFT1000   | SPFT2000 |
| Test parameters                 | Displacement, pressure                                   |          |
| Test range                      | Displacement: 0-80μm; Pressure: 0-100mN                  |          |
| Test accuracy                   | Displacement resolution: 1nm; Pressure resolution: 0.1mN |          |
| Stress-displacement curve       | •  | •        |
| Particle image observation      | •  | •        |
| Automatic displacement platform | /  | •        |
| Automatic pressure control      | •  | •        |
| Fully automatic software        | •  | •        |

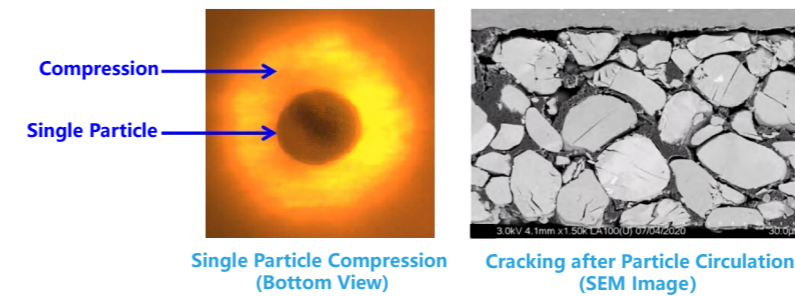
## B Product Introduction

► **Background:** Testing the crushing strength of battery material particles can be used to evaluate the pressure resistance of the material and guide the rolling process. Materials with high mechanical strength will have better subsequent cycle stability.

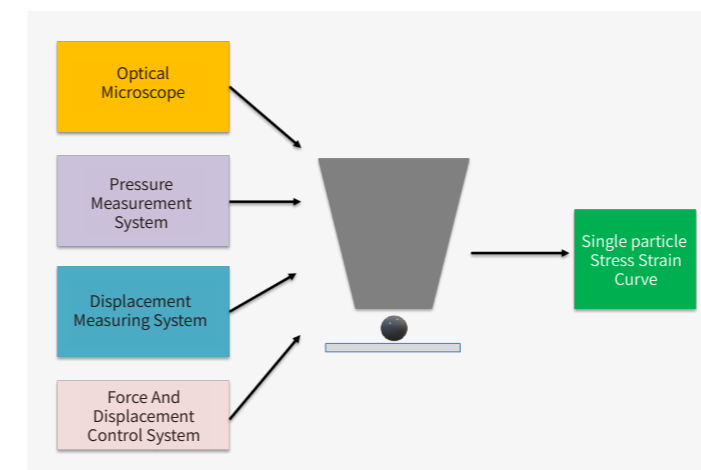


► **Testing Object:** Lithium battery positive and negative electrode materials (Positive: polycrystalline ternary, lithium-rich material; Negative: silicon-based, hard carbon, etc.; solid electrolyte)

► **Test Particle Size:** single particle size: 5~50 μm



## ► Equipment Composition



### Basic Functions

Particle Squeezing  
Recording force-displacement curve - looking for the "failure" point:  
force at which the particles are crushed (failure).

### Functional Modules

Displacement, pressure, software integrated control;  
Real-time photography and video recording of particles.

| Structural Functional Dversification  | Diverse Testing Modes  | Fully Automated Software  | Customized for Lithium-ion Batteries  | High cost-performance ratio   |
|---|--|---|---|---|
| <ul style="list-style-type: none"> <li>High-resolution optical imaging</li> <li>Displacement precision control</li> <li>Optical system inverted design</li> <li>XY automated displacement platform</li> </ul> | <ul style="list-style-type: none"> <li>Displacement control mode</li> <li>Pressure control mode</li> <li>Fatigue testing mode</li> </ul> | <ul style="list-style-type: none"> <li>Real-time display of force displacement curve</li> <li>One-click data analysis</li> <li>Real-time observation and logging. Particle crushing process.</li> </ul> | <ul style="list-style-type: none"> <li>Cathode material</li> <li>Anode material</li> <li>Precursor material</li> <li>Solid electrolyte materials</li> </ul> | <ul style="list-style-type: none"> <li>With the same functionalities, the price is much lower than similar instruments abroad.</li> </ul> |

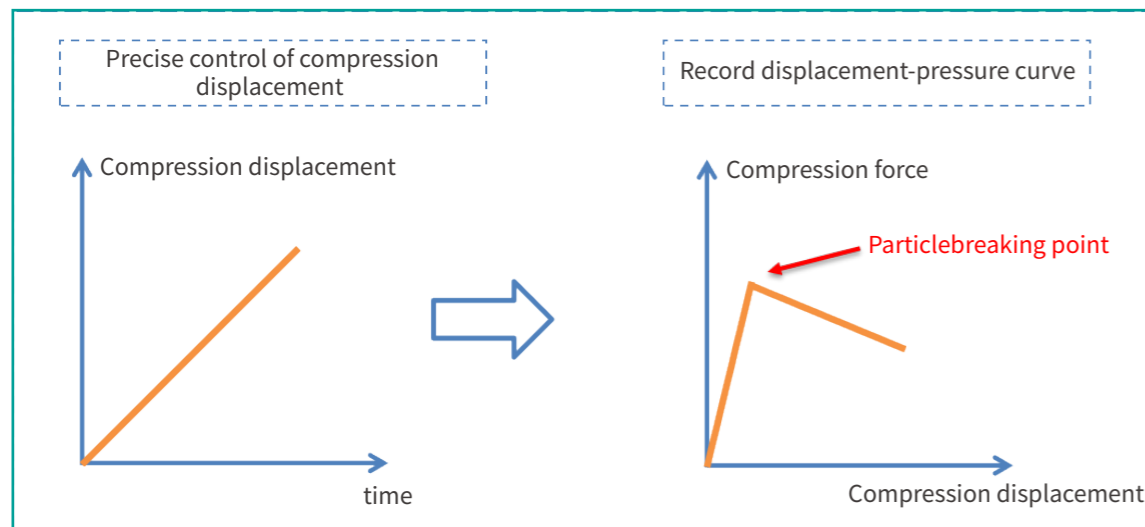
## C Testing Program

► **Testing Method:** Disperse the powder into the liquid. Add it dropwise to the glass slide. Locate the single particle under an optical microscope. Control the pressure head to press down at a constant speed. Collect the force and displacement curves during the particle compression process and calculate the mechanical properties of the single particle.

► **Test Parameters:**

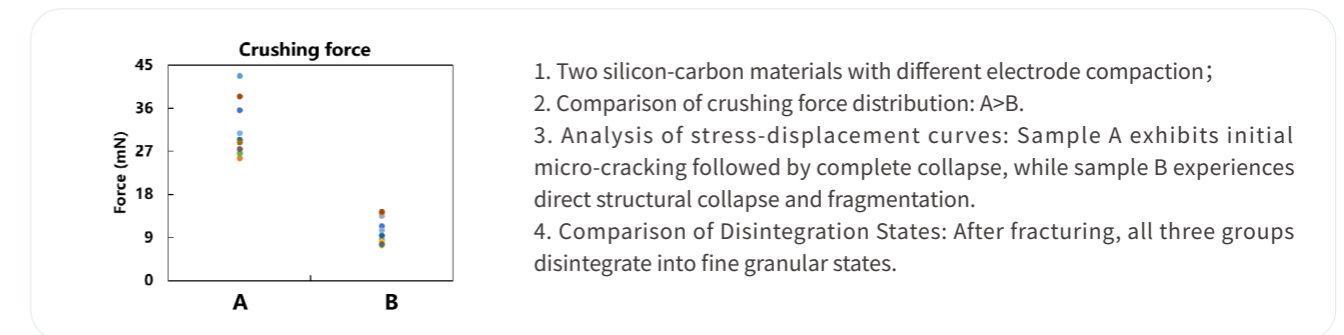
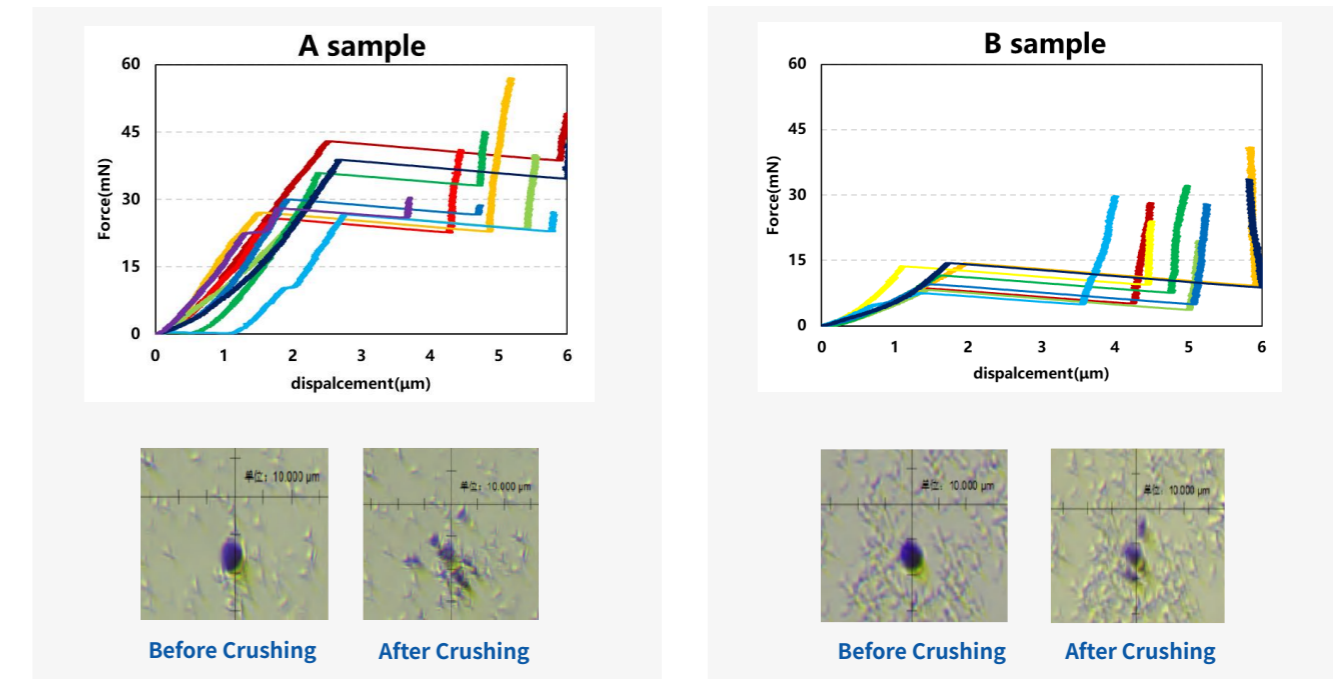
- Magnification: up to 1200 times;
- Pressure test range: 0-100 mN;
- Pressure test accuracy:  $\pm 0.1$  mN;
- Minimum displacement unit: 10nm;
- Data collection frequency 1000HZ;

Comply with national standard GB/T 43091-2023 "Powder Compressive Strength Test Method"

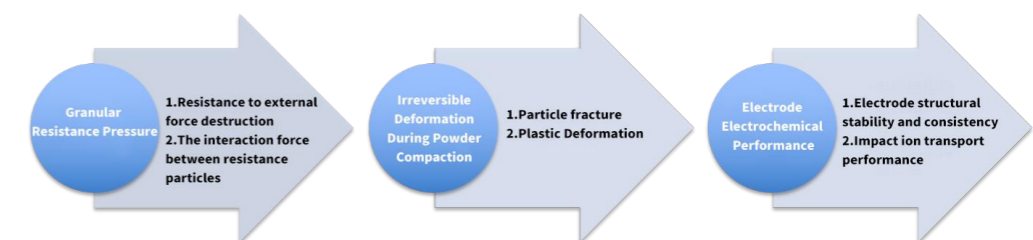


## D Application Case

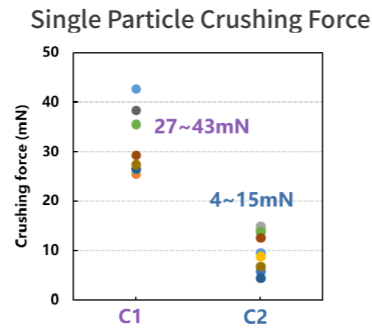
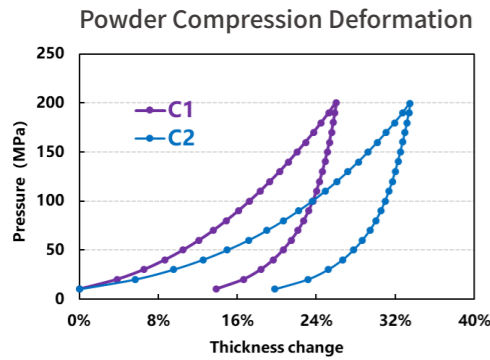
### ► Anode Material—SiC



### ► Particle Compression Resistance and Powder Compaction



### Case 1: Two Different Pure Carbons

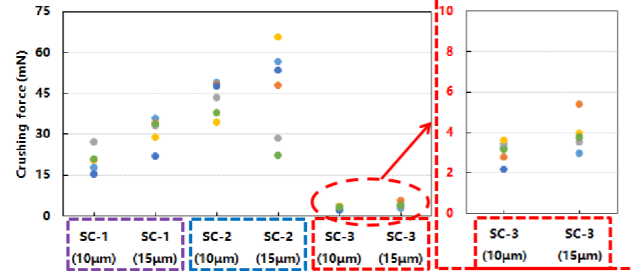


| Material | Irreversible Deformation Parameter | Maximum Deformation Value |
|----------|------------------------------------|---------------------------|
| C1       | 13.8%                              | 26.0%                     |
| C2       | 19.8%                              | 33.5%                     |

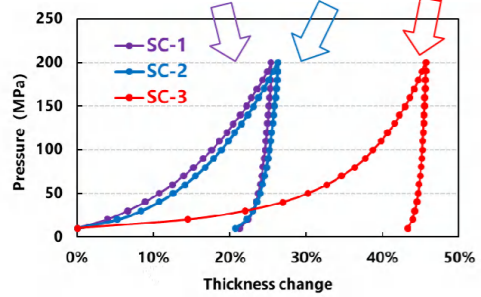
The compressive resistance of particle level C1 is stronger. Corresponding to the powder end, C1 has a higher compression modulus than C2, with both maximum deformation and irreversible deformation smaller than C2.

### Case 2: Three Different Carbon-Silicon Materials

Single Particle Crushing Force



| Material | Irreversible Deformation Parameter | Maximum Deformation Value |
|----------|------------------------------------|---------------------------|
| C1       | 13.8%                              | 26.0%                     |
| C2       | 19.8%                              | 33.5%                     |
| C2       | 19.8%                              | 33.5%                     |

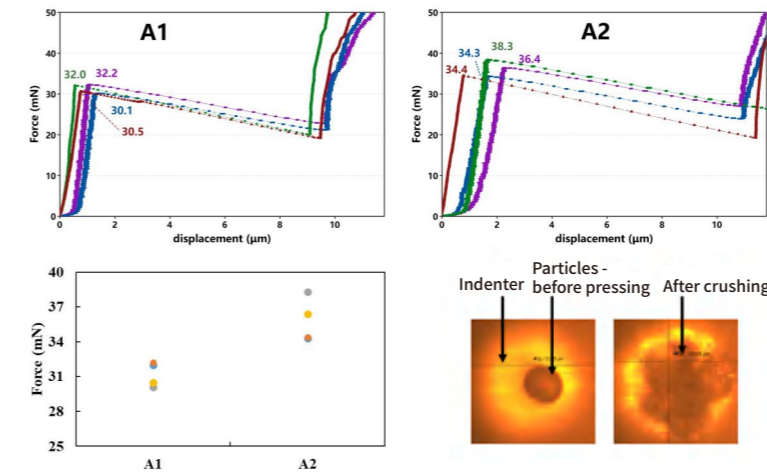


SC-3 has weaker compressive strength of its particles, resulting in significantly larger maximum deformation and irreversible deformation when the powder is compressed compared to the other two materials.

Powder Compression Deformation

### Ternary Cathode Material—NCM811

#### Case 1

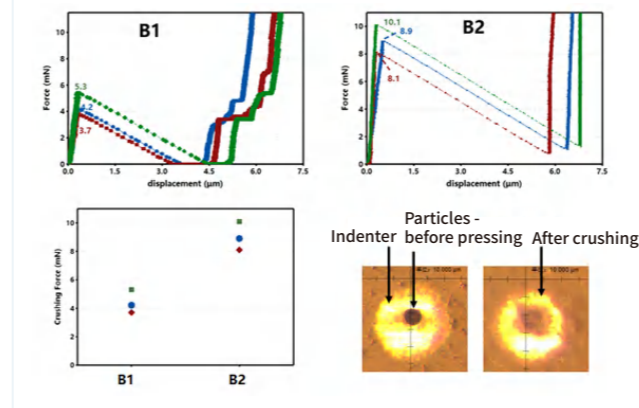


1. Two ternary materials A1 and A2 are sintered from the same precursor, but the sintering process is different. The particle size D50 is 18 µm.

2. The compression resistance of A2 is better than that of A1, and changing the sintering process can improve the material hardness to a certain extent. Single particle mechanical property characterization methods can provide guidance for the sintering process of materials.

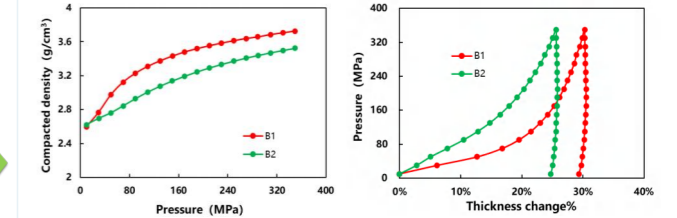
#### Case 2

Single Particle Testing

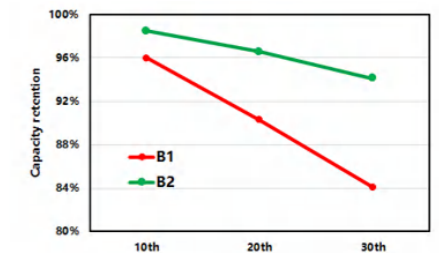


1. Two ternary materials, B1 and B2, are sintered from different precursors, and the particle size D50 is both 9.5 µm;  
2. The phenomena during particle crushing differ; powder compaction varies; discharge cycling performance differs.

Powder Testing



Discharge Testing



▶ After assembling into half-cells following the same procedure, cycling at 3.0~4.3V, 0.5C, and 45, sample B2 exhibits better cycling stability.

# Highly-Precision Testing System For Solid Electrolyte

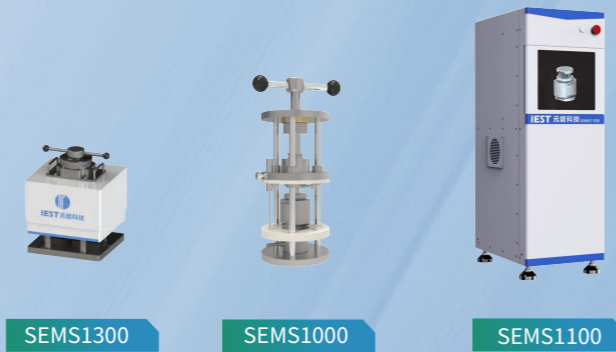


Scan QR code for the details



## A Creative Solutions

UEST has cooperated with Xiamen University to create the first multi-functional testing system dedicated to solid electrolyte samples, which is a fully automatic measuring equipment for the electrochemical performance of solid electrolytes that integrates tablet pressing, testing, and calculation. The system adopts an integrated design, including a pressurization module, an electrochemical test module, a density measurement module, a ceramic sheet pressing and clamping module and is suitable for testing various electrolytes such as oxides, sulfides, and polymers.



SEMS1300

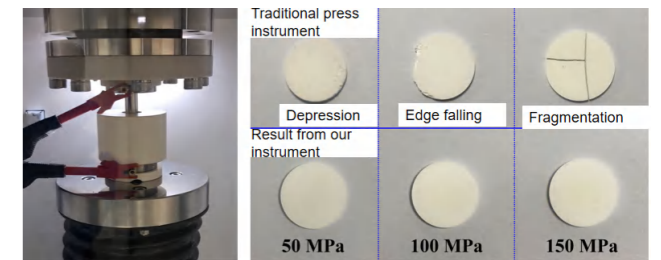
SEMS1000

SEMS1100

## B Application Case

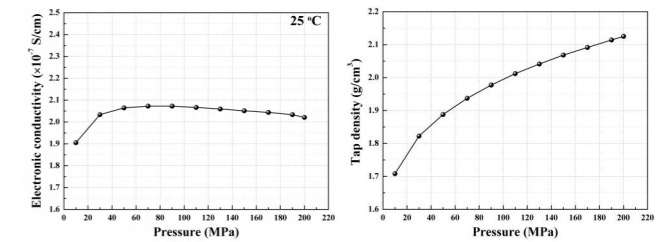
### (1) Powder production

The equipment can be used to tablet the powder samples under different pressure conditions, and the tablets obtained by SEMS are intact and free of cracks.



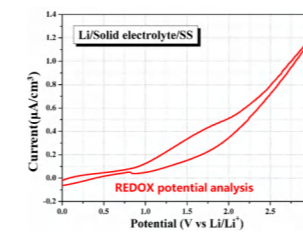
### (2) Electronic Conductivity & Compacted Density

Through the DC polarization (DP) module of SEMS, the electronic conductivity and compaction density of solid electrolyte under different pressures can be obtained automatically.



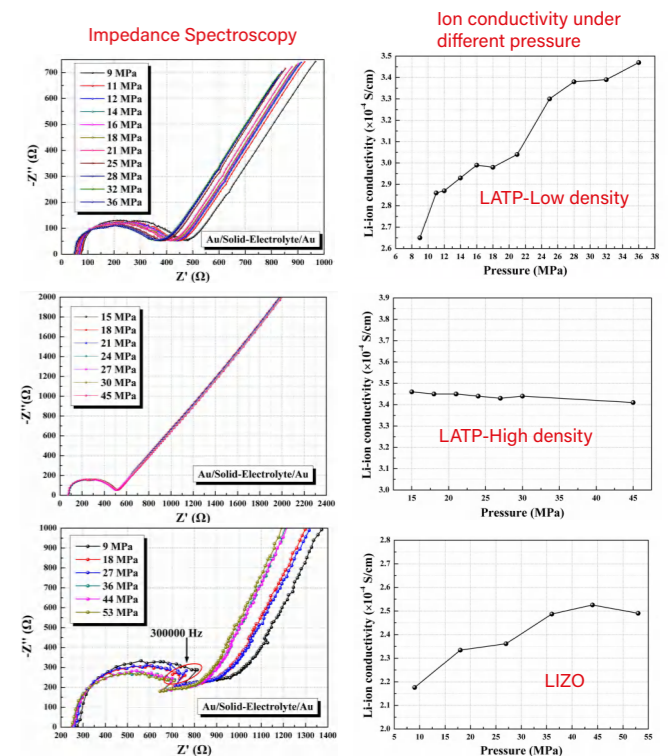
### (3) Electrochemical stabilization window

Through the cyclic voltammetry (CV) module of SEMS, it is possible to analyze the electrochemical stability window of solid electrolyte under different pressure.



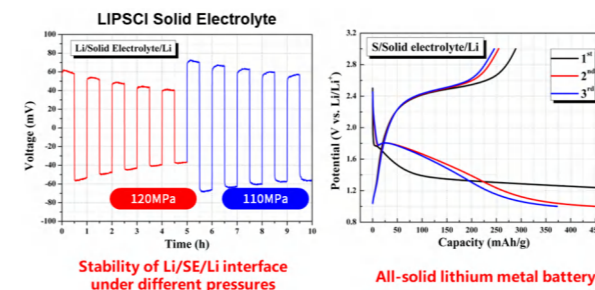
### (5) Ionic conductivity

10MHz~0.1Hz Voltage disturbances 10mV  
Through the electrochemical impedance spectroscopy (EIS) module of SEMS, the ionic conductivity of solid electrolyte under different pressures can be obtained automatically.



### (4) Solid-state battery cycling performance

Through the charge-discharge test (CD) module of SEMS, the cycle performance of solid lithium metal battery under different pressure and different electrochemical parameters can be analyzed.





# Battery Slurry Resistance Analyzer



Scan QR code for the details

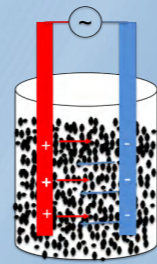


## A Slurry Resistivity Test Principle

Test Methods: Put a certain volume of slurry (~80mL) into the measuring glass, insert a clean electrode pen, start the software, start to test the change of the slurry resistivity at the three pairs of electrodes with time and save it to the file.

Main features:

1. Separate the voltage and current lines, eliminate the influence of inductance on voltage measurement, and improve the accuracy of resistivity detection;
2. The disc electrode with a diameter of 10mm ensures a relatively large contact area with the sample and reduces the test error;
3. It can monitor the change of resistivity with time at three positions in the vertical direction of the slurry in real time;



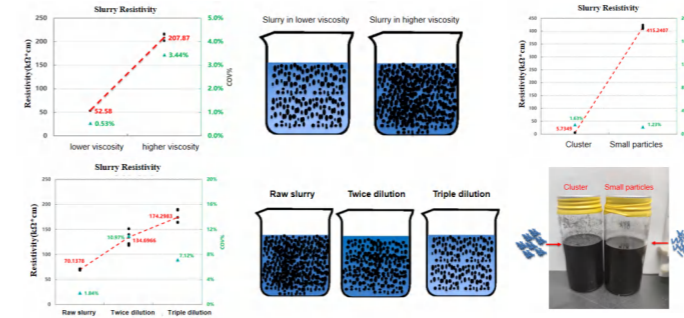
$$\text{Resistivity } (\Omega \cdot \text{cm}): \rho_e = \frac{U}{I} \times \frac{S}{l}$$

## B Specification Parameter

| Product model             | BSR2300            |   |               |
|---------------------------|--------------------|---|---------------|
| Resistivity range         | 2.5Ω*cm~50MΩ*cm    | Resistivity accuracy/resolution   | ±5%/0.1Ω*cm   |
| Conductivity range        | 0.02μS/cm~400mS/cm | Conductivity accuracy/resolution  | ±5%/0.01μS/cm |
| Temperature range         | -20~120°C          | Temperature accuracy/resolution   | ±0.5°C/0.1°C  |
| Number of test electrodes | three pairs        | Note: IEST is committed to continuous improvement of our products. If there is a technical modification, we will not notify you otherwise! Thank you for understanding. |               |

## C Application Case

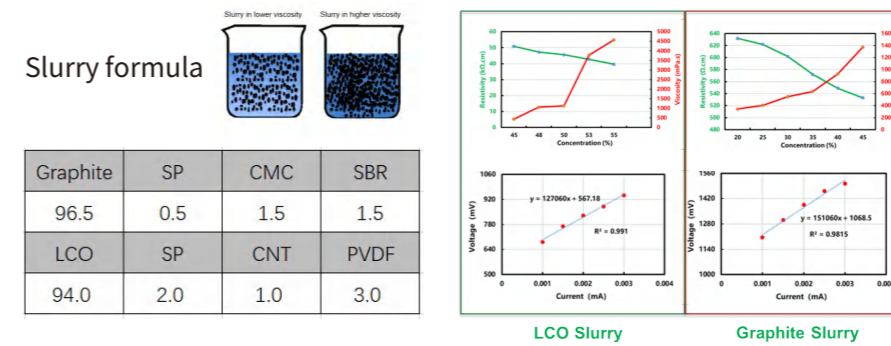
### (1) Evaluation of Conductive Agent Slurry with Different Formulations



When the viscosity, concentration and dispersant type of the conductive agent are changed, the resistivity also changes!

In the future, specifications can be formulated for the slurry resistivity of a certain fixed viscosity, and the stability of the slurry process can be monitored!

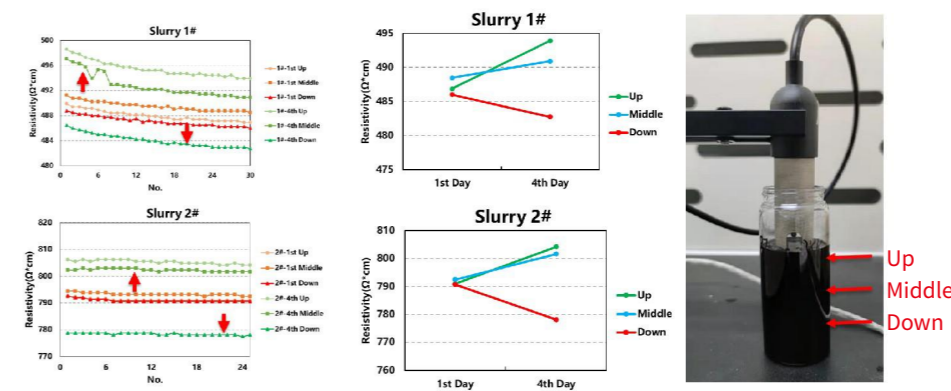
### (2) Concentration-Viscosity-Resistivity Correlation



The resistivity of the slurry decreases with the increase of the concentration, and the change of the viscosity is also inversely proportional to the relationship;

The I-V curve test of these two types of slurries basically conforms to Ohm's law, and the current and voltage have a linear relationship, indicating that the slurries are mainly electronic conductors;

### (3) Slurry Settling Performance



Test resistivity with different resting time.

On the first and fourth day of testing, the resistivity of the upper and middle channels increased, while the resistivity of the lower channel decreased, indicating that after four days of shelving, the slurry shows obvious settlement.

Subsequently, a shelving period can be formulated for a certain of slurry according to the change of the resistivity to ensure the uniformity of the slurry!

# Battery Electrode Resistance Analyzer



Scan QR code for the details



## A Differences between different models of BER series

| Model               | BER2100  | BER2200  | BER2300  | BER2500  |
|---------------------|--|--|--|--|
| Pressure method     | Cylinder (air source required, pressure range:5~35Mpa) |  | Servo motor(no air source required, pressure range:5~60Mpa)              |  |
| Testable parameters | Resistance, pressure, temperature and humidity         | Resistance, resistivity, conductivity, pressure, intensity of pressure, temperature and humidity |  | Resistance, resistivity, conductivity, pressure, intensity of pressure, temperature and humidity, thickness, compaction density                  |
| Feature             | Single point test                                      | Single point test<br>Continuous testing  | Single point test;Continuous testing; Variable pressure mode             |  |
|                     | Electrode resistance under constant pressure           | Electrode resistance,resistivity, conductivity under constant pressure                           | Electrode resistance, resistivity, conductivity under constant pressure  | Electrode resistance, resistivity, conductivity, thickness, compaction density, under constant pressure  |
|                     |  | Fully automatic measurement software   | Electrode resistance, resistivity, conductivity under different pressure | Electrode resistance, resistivity, conductivity, thickness, compaction density, under different pressure   |
|                     |  |  | Fully automatic measurement software                                     | The relationship between electrode resistance, resistivity, conductivity, thickness and compaction density, Fully automatic measurement software |

Note:IEST is committed to continuous improvement of our products. If there is a technical modification, we will not notify you otherwise! Thank you for understanding.

## B Testing method and principle

**Test parameters:**The battery electrode resistance analyzer (BER series) adopts the double-plane pressure-controllable disk electrode to directly measure the overall resistivity of the real electrode, that is, the sum of the coating resistance, the contact resistance between the coating layer and current collector and the current collector resistance.

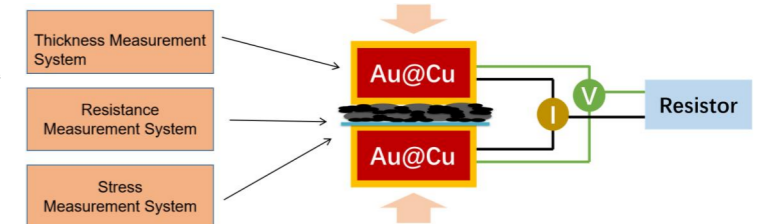
- Feature:**
- 1.Directly measure the longitudinal resistance of the real electrode, that is, the sum of the coating resistance, the contact resistance between the coating layer and current collector and the current collector resistance;
  - 2.Separate the voltage and current lines, eliminate the influence of inductance on voltage measurement, and improve the detection accuracy;
  - 3.Equipped with standard resistance block and thickness block measured by a third-party metrology institute.

Calculation formula:

$$\text{Compaction Density(g/cm}^3\text{): } D = \frac{m_{\text{Area density}}}{L_{\text{Coating Thickness}}}$$

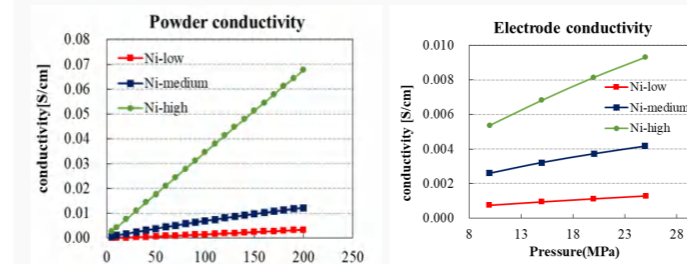
$$\text{Resistance(Ohm): } R = \rho \frac{l}{S}$$

$$\text{Conductivity (S/m): } \sigma_e = \frac{1}{\rho} = \frac{l}{RS}$$



## C Application-Material Evaluation

### (1) Material Evaluation : Correlation between powder conductivity and electrode conductivity

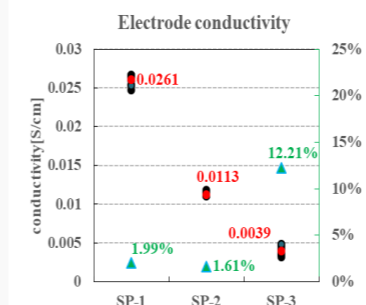


Result analysis:

- ①Adjust the Ni content in the ternary material, and test the electrical conductivity of the powder, it can be found that as the Ni content increases, the electrical conductivity of the powder increases;
- ②Comparing three ternary electrode pieces with different Ni content, it can also be obtained that the conductivity of the electrode piece increases with the increase of Ni content;

The powder conductivity and electrode conductivity have the same trend!

### (2) Conductivity evaluation of conductive agents



Constant pressure test: 25MPa,hold pressure for 25s and collect 15points;

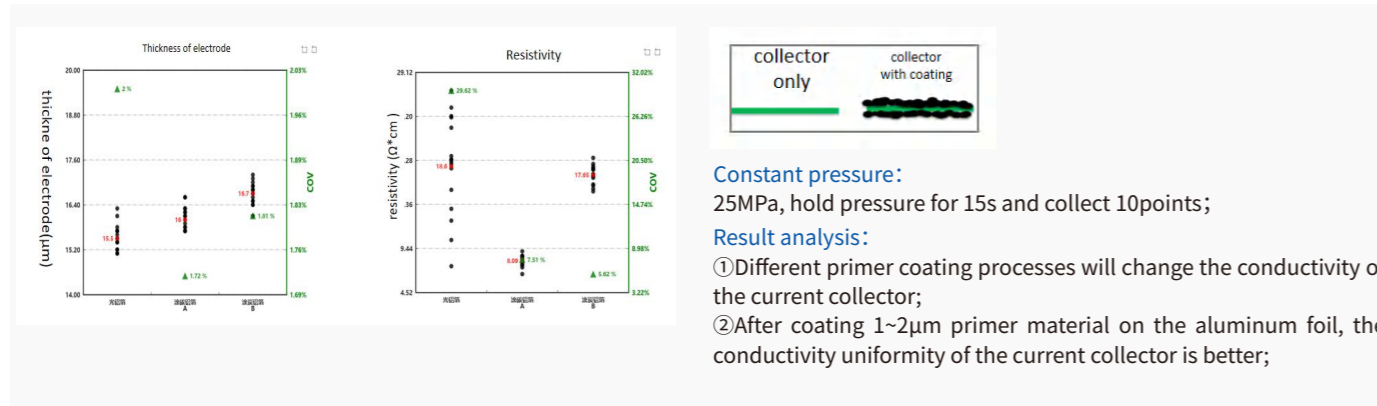
Result analysis:

- ①Compared with the conductivity of three conductive agents, SP-1>SP-2>SP-3;
- ②Compared with the dispersibility of three conductive agents, the COV value of SP-3 is largest which means that the dispersion uniformity of SP-3 is poorest; the dispersibility of SP-1 and SP-2 is better;

Electrode conductivity characterization can be used to evaluate the conductivity and dispersion performance of conductive agents!

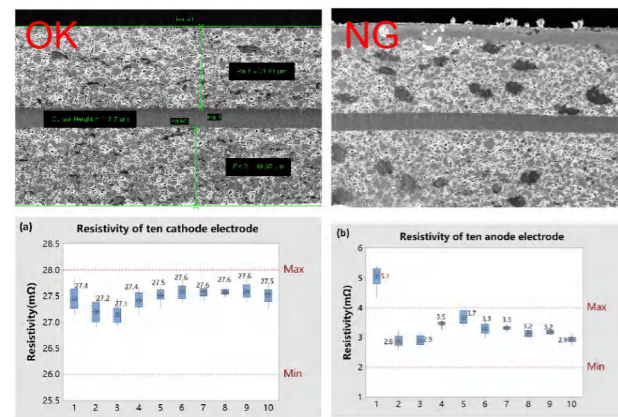
\* Coefficient of Variation COV = (Standard Deviation SD / Mean) × 100%

### (3) Evaluation of primer coated aluminum foil: bare aluminum foil, carbon coated aluminum foil A, carbon coated aluminum foil B



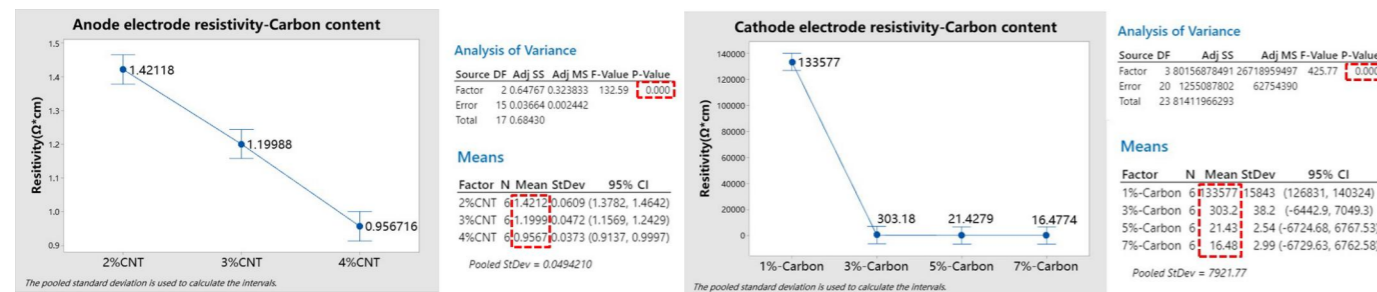
## D Application Case - Process Evaluation

### (1) Uniformity evaluation for the distribution of conductive agent



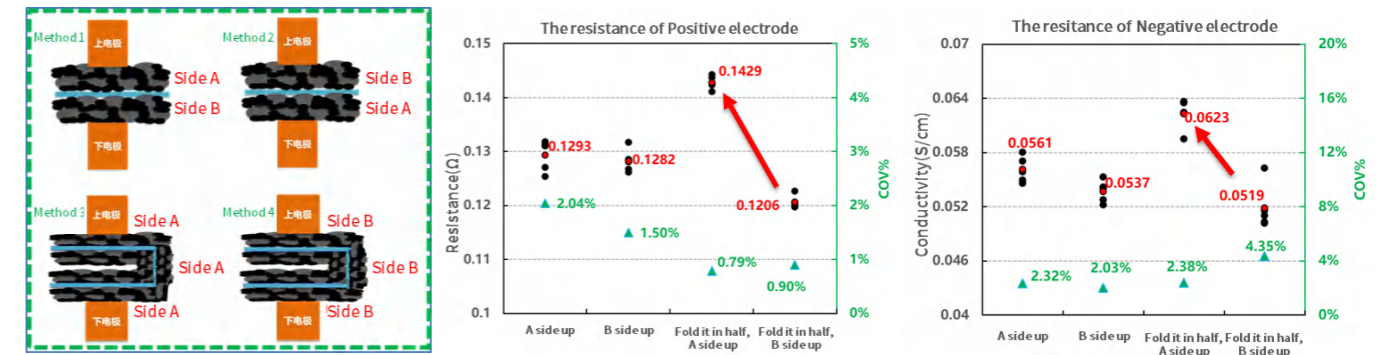
By using the resistance to monitor the coating quality of the electrode, an abnormal battery electrode can be quickly identified. It is useful to prevent the bad battery electrode from flowing into the process, and to save production costs.

### (2) Positive and negative electrodes with different conductive agents



As the content of the conductive carbon increases, the resistivity of the ternary positive electrode decreases gradually. When the content of the conductive carbon is greater than 5%, the resistivity only decreases by a small amount. However, the resistivity of the graphite negative electrode decreases almost linearly with the increase of the content of conductive carbon.

### (3) Separate the resistivity of the A and B coating layers for the double-coating electrode



$$\textcircled{1} R_{\text{Total}} = R_{\text{A-Upper electrode}} + R_{\text{A}} + R_{\text{A-Foil material}} + R_{\text{Foil material}} + R_{\text{B}} + R_{\text{B-Foil material}} + R_{\text{B-Lower electrode}}$$

$$\textcircled{2} R_{\text{Total}} = R_{\text{B-Upper electrode}} + R_{\text{B}} + R_{\text{B-Foil material}} + R_{\text{Foil material}} + R_{\text{A}} + R_{\text{A-Foil material}} + R_{\text{A-Lower electrode}}$$

$$\textcircled{3} R_{\text{Total}} = R_{\text{A-Upper electrode}} + 2R_{\text{A}} + 2R_{\text{A-Foil material}} + R_{\text{Foil material}} + R_{\text{A-Lower electrode}}$$

$$\textcircled{4} R_{\text{Total}} = R_{\text{B-Upper electrode}} + 2R_{\text{B}} + 2R_{\text{B-Foil material}} + R_{\text{Foil material}} + R_{\text{B-Lower electrode}}$$

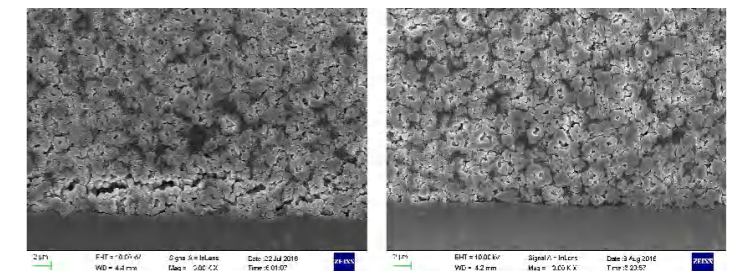
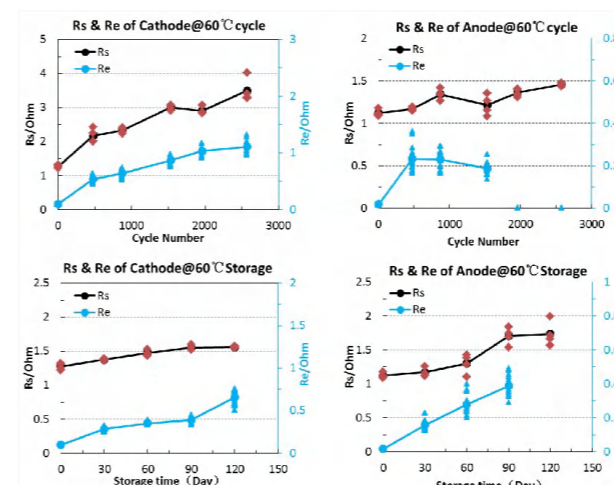
Test parameters: 25MPa test pressure, hold pressure for 15s, and test 5 parallel points for each group;

Result analysis:

- ① When the A side or the B side is facing up alone, the difference in the resistance and uniformity of the electrode sheet is small;
- ② The difference between the A side and the B side after folding is mainly due to the difference in the coating on the two sides, so this method can be used to judge the difference in the coating on the AB side;

## E Application Case - Failure Analysis

### (1) Analysis of electrode resistance during high temperature cycle&storage



The resistance of the cathode continues to increase with the increase of the cycle numbers, 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 reactions on the anode material surface.

# Electrode Tortuosity Tester & Separator Ion Conductivity Tester



Scan QR code for the details



## A Model and Parameters

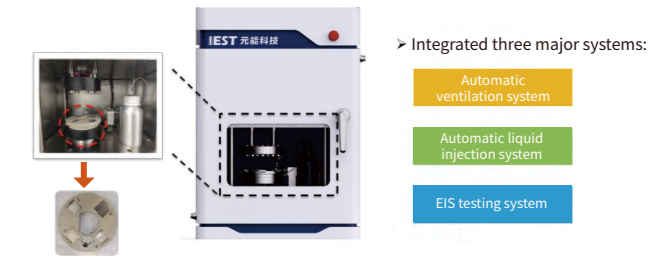
| Model               | EIC1400K  | EIC1400M                                    | EIC2400K   | EIC2400M                                    |
|---------------------|---|---|--|---|
| Channels number     | 4   |   | 4  |   |
| Auxiliary equipment | Glove box   |   | No additional auxiliary equipment required   |   |
| EIS test range      | 1500~0.1 Hz   | 100k~0.01 Hz                                | 1500~0.1 Hz  | 100k~0.01 Hz                                |
| Pressure range      | 0~20kg (variable pressure)  | 0~20kg (variable pressure)                  | 20kg   | 20kg  |
| Applicable samples  | positive and negative electrodes  | positive and negative electrodes, separator | positive and negative electrodes   | positive and negative electrodes, separator |
| Mold Size           | Φ60*61mm (W×H)  |   | A 110mm disc with four embedded channels of 19*19mm each (customizable).   |   |
| Test parameters     | ionic conductivity, MacMullin number  |   | Air pressure, dew point, ionic conductivity, MacMullin number, etc.  |   |
| Features            | <ul style="list-style-type: none"> <li>◆ Testing of separator ionic conductivity and electrode MacMullin number under different pressures.</li> <li>◆ The software interface displays test curves and allows for fitting of EIS curves to obtain parameters such as ionic conductivity and MacMullin number.</li> </ul> |   | <ul style="list-style-type: none"> <li>◆ Automatic ventilation to ensure a high-purity argon gas environment inside the chamber.</li> <li>◆ Automatic liquid injection</li> <li>◆ Assemble multi-channel symmetric batteries rapidly and test EIS.</li> <li>◆ The software interface displays test curves and can fit the EIS curve to obtain parameters such as ion conductivity and MacMullin number.</li> </ul> |   |

Note: IEST is committed to continuous product improvement. Any changes to technical specifications will be made without prior notice.

## B Creative Solution One

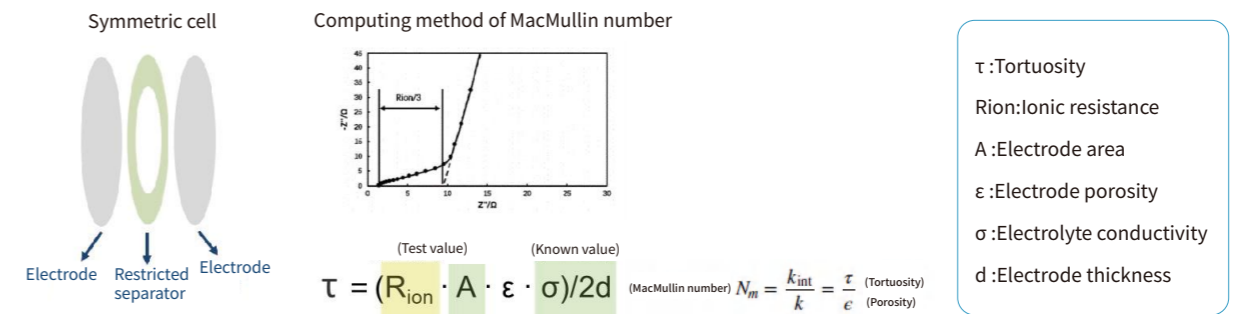
### ◆ Creative Solution:

1. Calculate the MacMullin number of the electrode by testing the EIS of the symmetric cell.
2. Simplify assembly, automate testing and analysis processes, streamline operation steps, and enhance testing efficiency.
3. Synchronous testing across four channels.

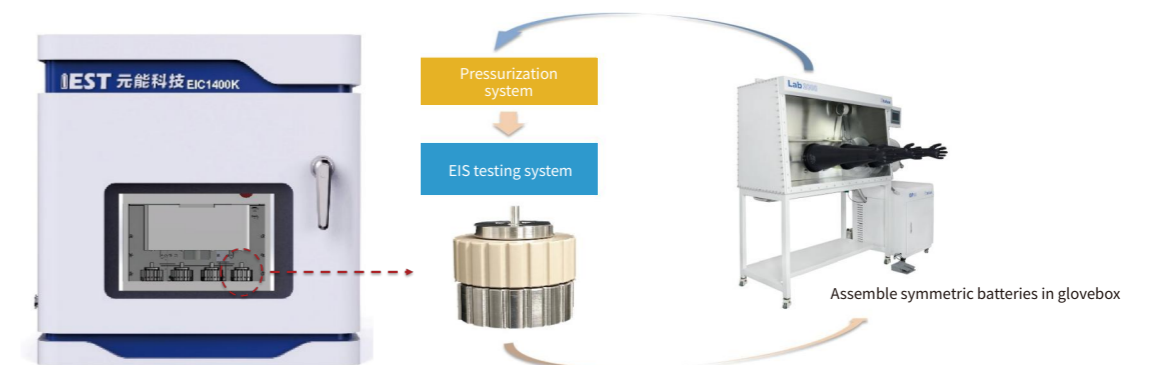


### ◆ Testing Principle:

1. Assemble symmetric batteries and conduct EIS testing.
2. As shown in the figure below, linearly fit the high-frequency and low-frequency segments of the EIS spectrum separately. The difference between the intersection of the fitting curves and the X-axis multiplied by 3 is the ionic resistance of the electrode coating
3. Using the following formula, the MacMullin number can be calculated. This allows for the pre-evaluation of the electrochemical performance of the electrode after it is assembled into a cell. Therefore, characterization and comparison of the ion conductivity of the electrode coating are particularly important.



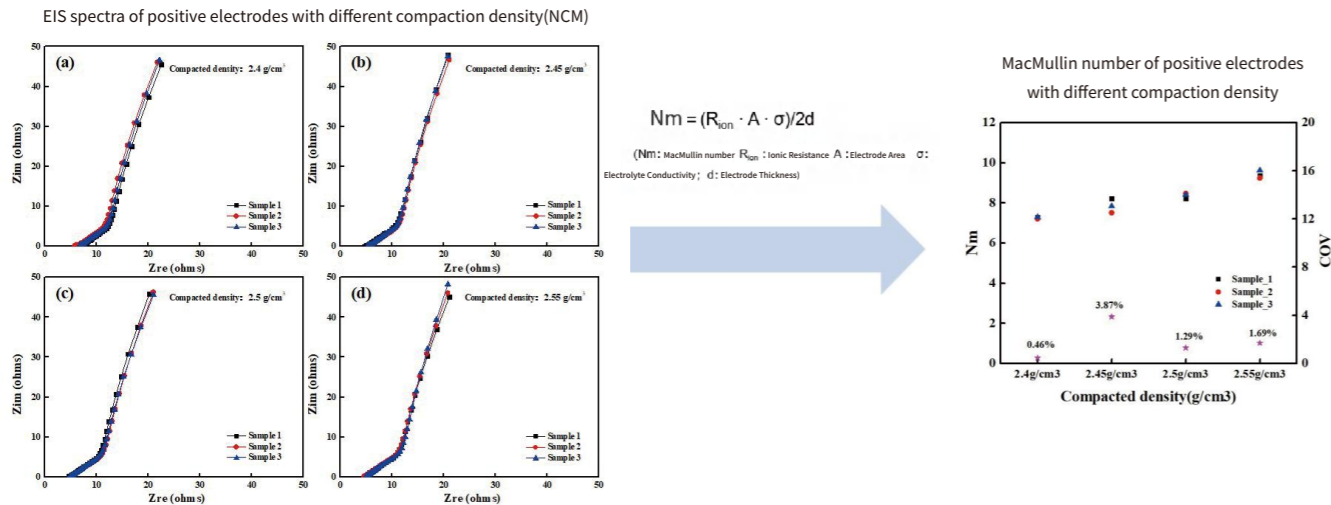
## C Creative Solution Two



- Multi-channel testing
- Variable pressure testing
- Fast EIS testing
- Data fitting and analysis

## D Application case

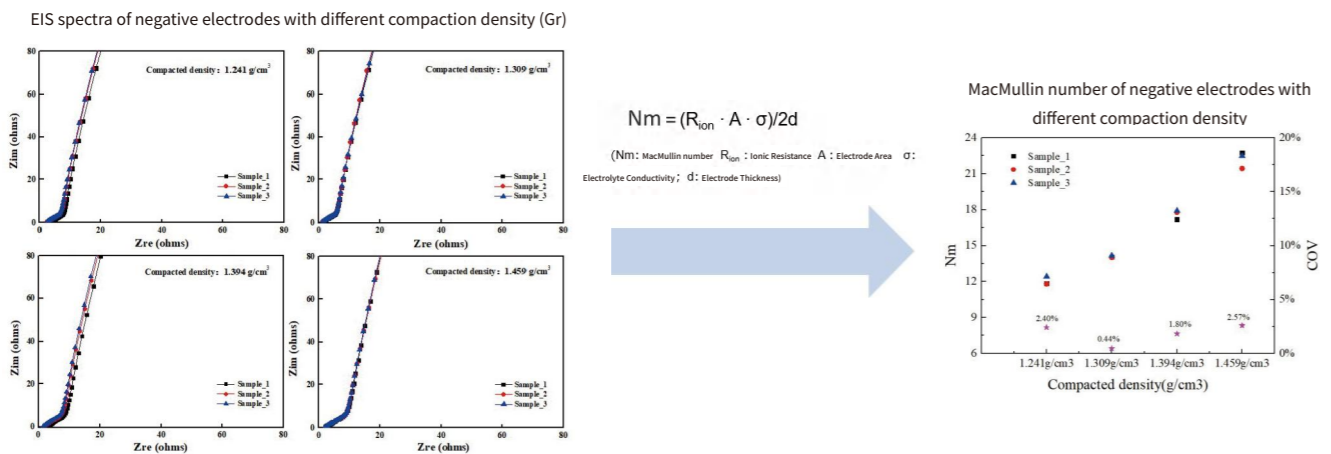
### (1) Different compaction density of positive electrodes



#### Summary:

- The consistency of EIS testing for symmetric battery of electrodes is generally good.
- Within a certain range of compaction density, as the compaction increases, the ion resistance/MacMullin number also increases.

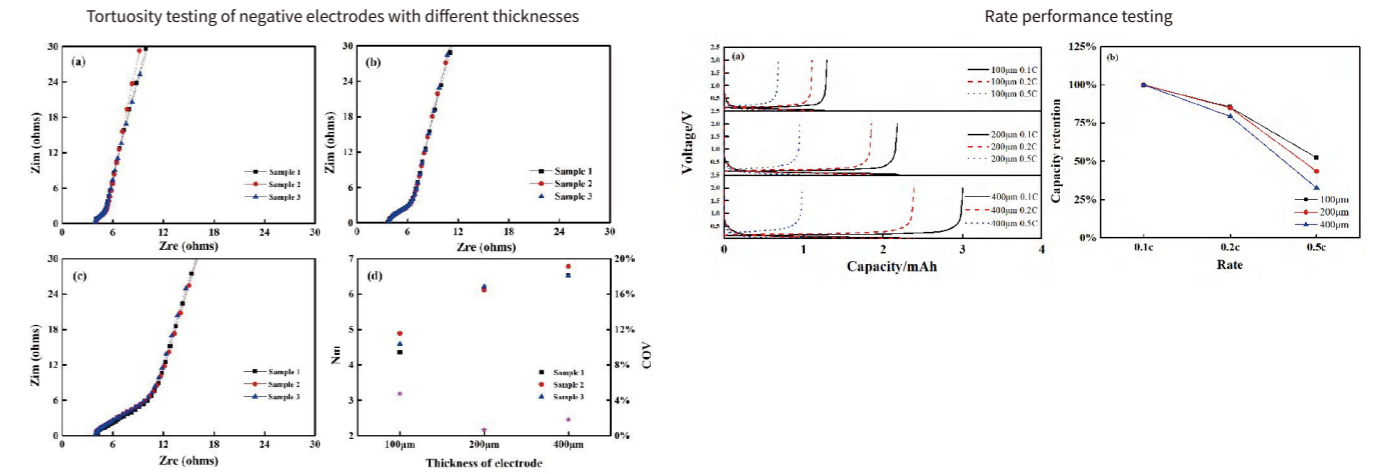
### (2) Different compaction density of negative electrodes



#### Summary:

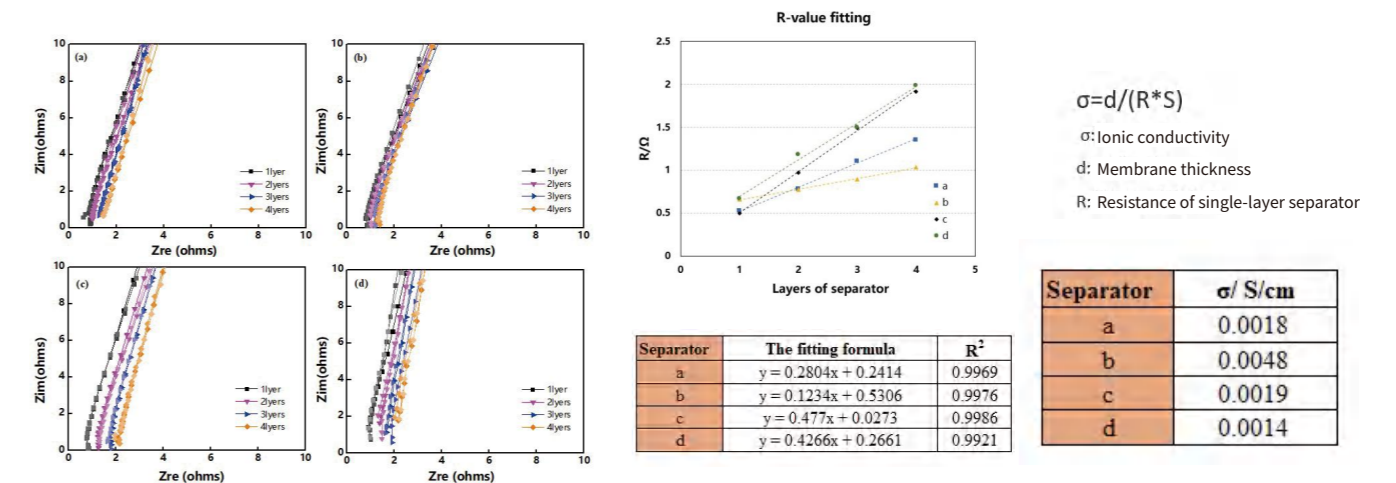
- The consistency of EIS testing for symmetric battery of electrodes is generally good.
- Within a certain range of compaction density, as the compaction increases, the ion resistance/MacMullin number also increases.

### (3) The correlation between electrode tortuosity and electrochemical performance (Gr negative electrodes of different thicknesses)



**Summary:** As the thickness of the electrode increases, its tortuosity also increases. However, the rate performance of the battery decreases with increasing thickness. This indicates that the rate performance of the battery decreases with increasing tortuosity. There is a certain correlation between electrode tortuosity and rate performance of battery.

### (4) Different coated separators (Ionic conductivity testing of four different coated separator)



#### Summary:

- Test the EIS of 1-4 layers of separators to obtain R1, R2, R3, R4.
- Plot a curve with the number of separator layers as the x-axis and separator resistance as the y-axis. Calculate the slope and linear fitting degree of the curve, with the linear fitting degree  $\geq 0.99$ .
- Calculate the separator ionic conductivity according to the formula.

# In-Situ Gassing Volume Analyzer



Scan QR code for the details



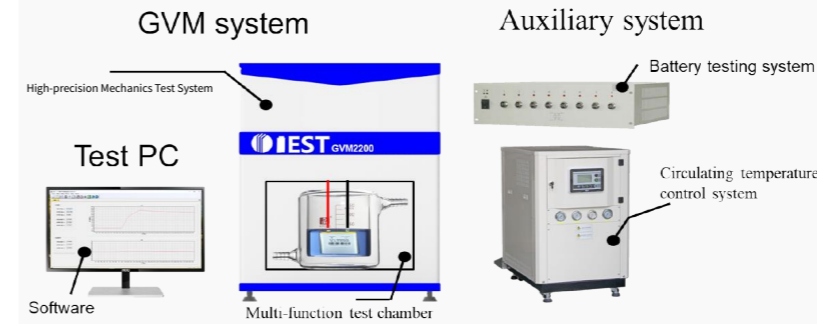
## A Differences between different models of GVM series

| Model  | GVM2100, GVM2200   | GVM2150, GVM2250   |
|--|--|--|
| Channel                                      | single channel (single cell)<br>two channels (two cells) | single channel (single cell)<br>two channels (two cells) |
| Maximum quality of pouch cell to be measured | 1000g  | 5000g  |
| Cell test temperature                        | 20~85°C  | 20~85°C  |
| Volume resolution                            | ≤1uL   | ≤10uL  |
| Volume accuracy                              | ≤10μL  | ≤30μL  |
| System stability                             | ≤10μL (RT25°C, ≤30min),<br>≤20μL (RT25°C, 30min~12h)     | ≤30μL (RT25°C, ≤30min),<br>≤50μL (RT25°C, 30min~12h)     |

Maximum size of detectable cell (excluding pole lug): 220\*160mm (Special sizes can be customized)

Note: IEST is committed to continuous improvement of our products. If there is a technical modification, we will not notify you otherwise! Thank you for understanding.

## B Creative solution - in-situ gas production volume monitor



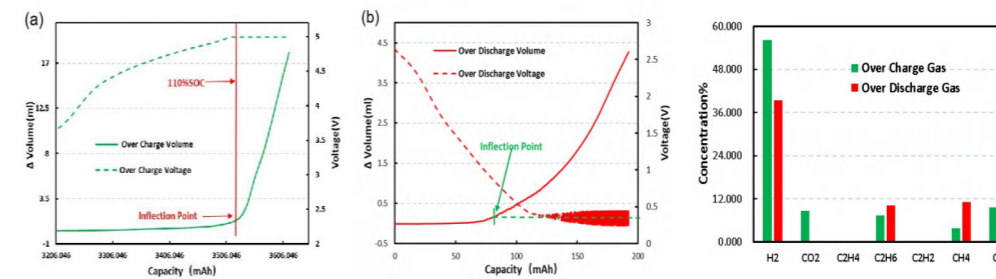
**High-precision Mechanics Test System:** long term & in-situ monitoring, and meet the accuracy requirements.

**Dedicated Test Software:** In-situ collect and display the data measured by the mechanics test system, and automatically draw the volume change curves.

**Auxiliary System:** Special structure design, convenient to be compatible with supporting auxiliary system, and realize the temperature adjustment.

## C Application Case - Overcharge Gas Production Analysis

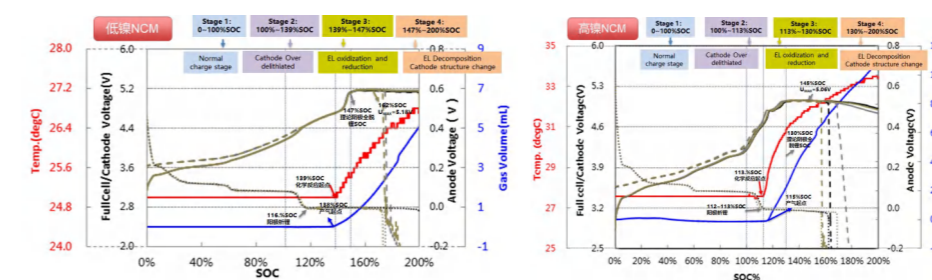
### (1) Analysis of overcharge and overdischarge of LFP batteries



LFP/Graphite System battery;  
0.5C CCCV to 5V;  
0.5C DC to 0V;

As the cell is overcharged or overdischarged, the starting point of gas production can be detected in real time; Gas chromatography analyzes the gas composition under these two working conditions. In addition to the same gas type as the over-discharge cell, a relatively high content of CO and CO<sub>2</sub> gas is also detected.

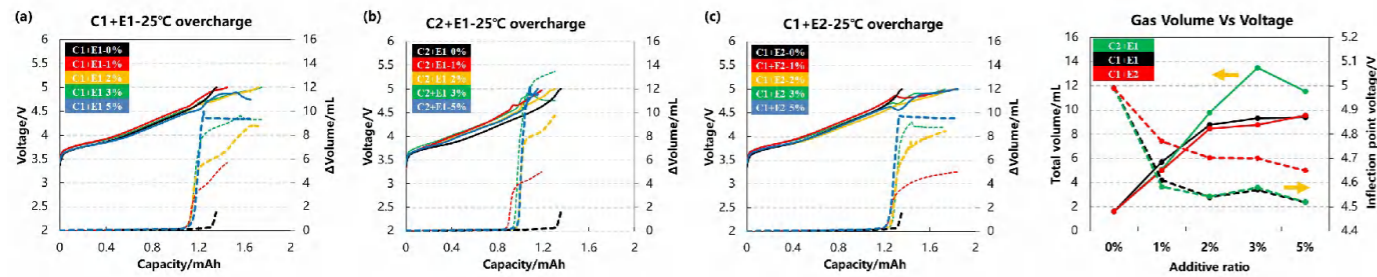
### (2) Gassing Analysis for Different NCM Materials During Overcharging



With the increase of the Ni content in NCM materials, it can be found that the starting SOC point of the gas production decreases from 138% to 115%.

By monitoring the normal charging process of the cells and the volume and temperature changes during the overcharge process, and comparing these data to the three-electrode curves, we can accurately gain the starting voltage and the reaction rate of violent side reactions, which can help us analyze the overcharge performance of the materials quantitatively, and improve the R&D efficiency in a targeted manner.

### (3) Types and contents of different cathode materials and electrolyte additives

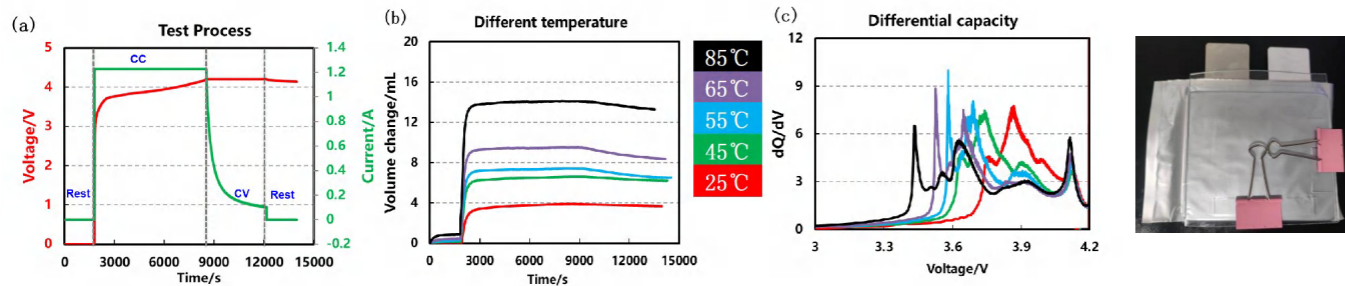


| The ratio of electrolyte additives | Gassing after overcharge to 5V(mL) |        |       | Voltage in gassing curve inflection point |       |       |
|------------------------------------|------------------------------------|--------|-------|---|-------|-------|
|                                    | C1+E1                              | C2+E1  | C1+E2 | C1+E1                                     | C2+E1 | C1+E2 |
| 0%                                 | 1.625                              | 1.625  | 1.625 | 4.99                                      | 4.99  | 4.99  |
| 1%                                 | 5.708                              | 5.068  | 5.005 | 4.61                                      | 4.583 | 4.77  |
| 2%                                 | 8.786                              | 9.783  | 8.457 | 4.54                                      | 4.543 | 4.70  |
| 3%                                 | 9.335                              | 13.479 | 8.785 | 4.57                                      | 4.58  | 4.70  |
| 5%                                 | 9.391                              | 11.522 | 9.549 | 4.52                                      | 4.52  | 4.65  |

Comparing the gassing behavior of the LIBs under overcharging with different types and contents of the electrolyte additives, it can be found that the reaction potential of additive-A is lower than that of additive-B, which can be a better additive to protect the LIBs under the overcharge condition.

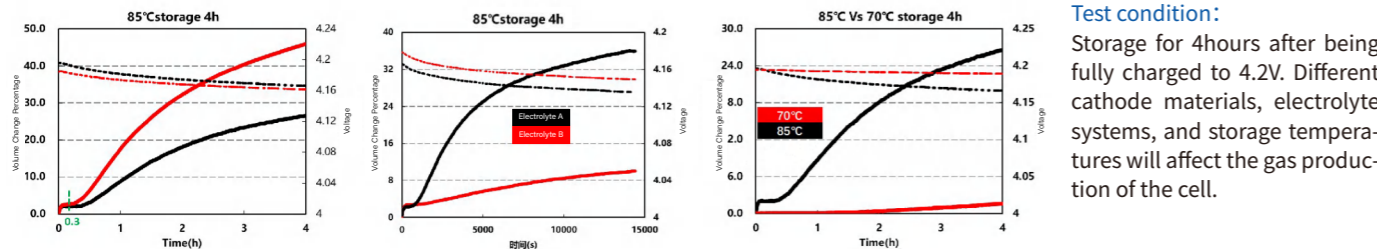
### D Application Case - Analysis of Formation and Gas Production

#### (1) Formation at different temperatures



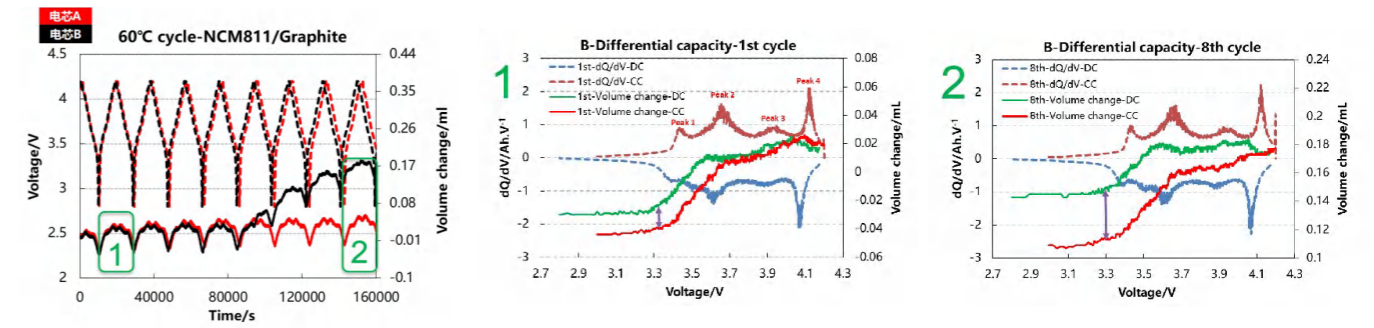
NCM/Graphite cells, 0.5C CC to 4.2V, theoretical capacity 2400mAh; As the formation temperature increases, the corresponding gas production also gradually increases; From the differential capacity curve, the increase of the formation temperature will reduce the polarization of each phase transition, but when it reaches above 55°C, the peak of the first phase transition will be sharper, which may be due to that the high temperature will increase the intensity of the formation reaction.

#### (2) Gas Production during the Storage Process



**Test condition:** Storage for 4hours after being fully charged to 4.2V. Different cathode materials, electrolyte systems, and storage temperatures will affect the gas production of the cell.

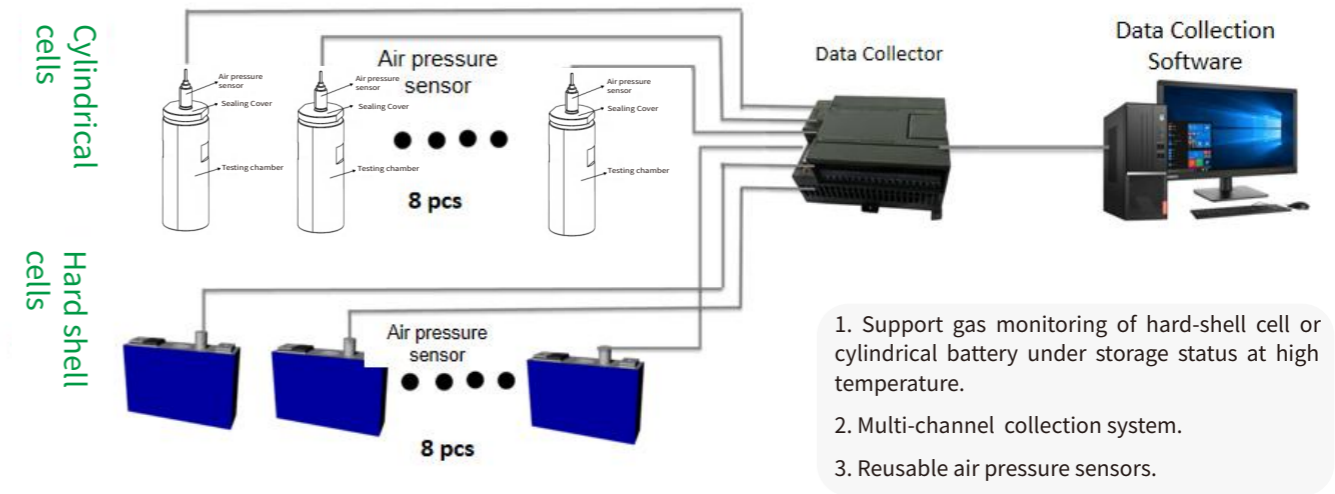
### (3) Cyclic gas production analysis - comparison of different ternary materials



Cell-A and Cell-B are made by different NCM materials. The volume change of Cell-B is larger than that of Cell-A during the long-term cycling, and the irreversible volume change also increase from 0.01 mL to 0.04 mL.

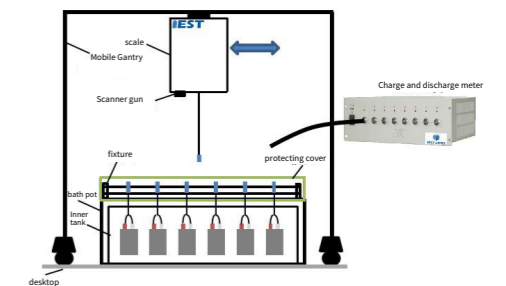
It can help to quantitatively analyze the cycling performance of different materials, modify the materials in a targeted manner, and improve the R&D efficiency.

### E In-Situ Gas Production Test System for Hard-Shell Cell



### F Multi-channel gassing test system for storage

The multi-channel gassing test system for storage adopts high-precision weighing balance and constant temperature bath, which can in-situ realize the detection of the gas production during the high-temperature storage process of the batteries, and is equipped with self-designed fixtures and charging and discharging equipment. The battery can also be charged and discharged during storing.



# In-Situ Cell Swelling Analyzer



Scan QR code for the details



## A Differences between different models of SWE series

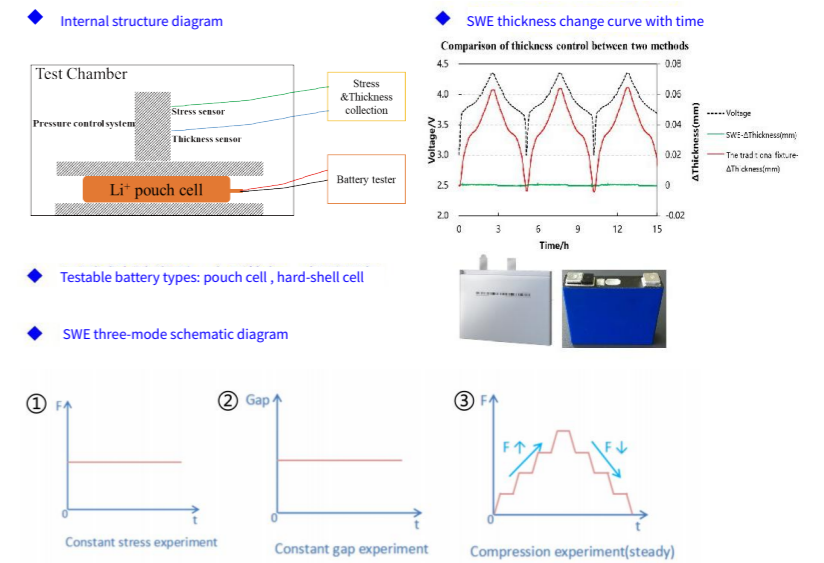
| Model  | SWE150P/T   | SWE1400L   | SWE2110, SWE2510  | SWE2100, SWE2500  |
|--|---|--|---|---|
| Pressing method  | Manual: manual pressurization to the required pressure  | Automatic: automatically controlled by software  |   |   |
| Testable parameter   | Cell expansion force&thickness<br>Pressure detection range: 0-50KN (could be customizable)  | Cell expansion force, Cell Initial Thickness, Cell temperature, Cell expansion thickness, Cell Stress-Strain Curve   |   |   |
| Function   | <ul style="list-style-type: none"> <li>Constant pressure or constant gap mode:                             <ol style="list-style-type: none"> <li>Can apply a force of 10-5000kg;</li> <li>The largest measurable cell size: 400*300*100</li> <li>Temperature control: optional -20°C-60°C</li> </ol> </li> <li>The software automatically collects testable parameters</li> <li>Software compatible with charging and discharging data</li> <li>Multiple units can be connected in parallel</li> <li>It can be placed in a high and low temperature box, the temperature range is -30-100°C</li> </ul> | <ol style="list-style-type: none"> <li>Number of channels:4</li> <li>Constant pressure mode (accuracy <math>\pm 20\mu\text{m}</math>)</li> <li>Pressure range:5T</li> <li>Provide high and low temperature environment:-20-60°C</li> </ol> | <ol style="list-style-type: none"> <li>Number of channels:1</li> <li>Constant pressure mode (accuracy <math>\pm 1\mu\text{m}</math>)</li> <li>Pressure range:1T (SWE2110), 5T (SWE2510)</li> <li>Provide high and low temperature environment:-20-80°C</li> </ol> | <ol style="list-style-type: none"> <li>Number of channels:1</li> <li>Constant pressure mode (accuracy <math>\pm 1\mu\text{m}</math>)</li> <li>Pressure range:1T (SWE2100), 5T (SWE2500)</li> <li>Provide high and low temperature environment:-20-80°C</li> </ol> |
| <ol style="list-style-type: none"> <li>Constant gap mode (accuracy <math>\pm 0.3\%F.S.</math>);</li> <li>Compression modulus mode;</li> <li>Software compatible with charging and discharging data;</li> <li>Automatic measurement software: automatic collection of expansion force, expansion thickness, cell temperature, free choice of mode, free setting of experimental parameters;</li> <li>Multiple units can be connected in parallel to realize synchronous testing;</li> </ol> |   |  |   |   |
| Note:IEST is committed to continuous improvement of our products. If there is a technical modification , we will not notify you otherwise!Thank you for understanding.   |   |  |   |   |

## B Swelling Behavior of The Lithium Ion Battery(LIB)

In situ swelling analysis system: Combined with the highly stable automatic platform and the high-precision thickness and mechanical sensors, it can achieve long-term stability and accurately detect the expansion thickness and the expansion force under different conditions.

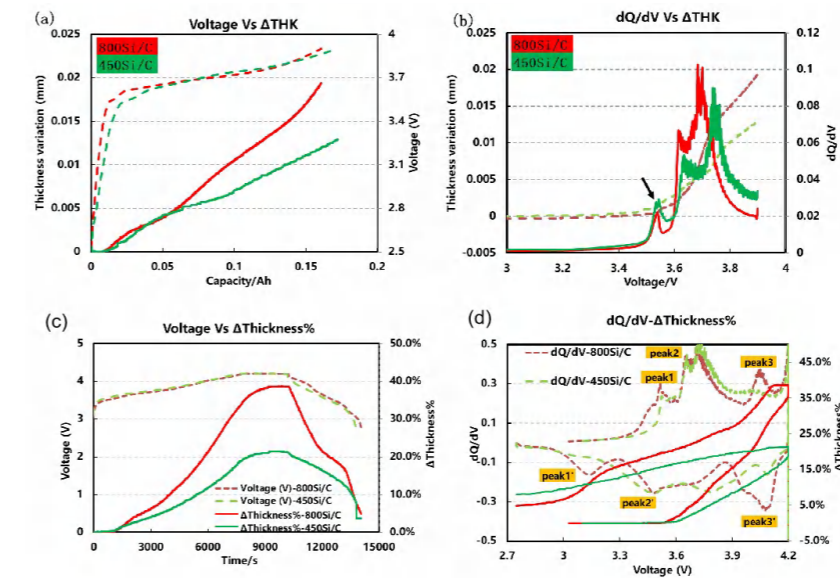
Multi-function test modes: the constant pressure and constant gap test modes can be realized for the cell, and the performance of the cell under different stress conditions can be evaluated.

High precision control:The traditional fixture will generate  $\sim 70\mu\text{m}$  deformation under the constant gap testing mode, which leads to the inaccurate swelling force test. However, the in-situ SWE analysis system of IEST can control the change of the gap within  $\sim 1\mu\text{m}$  by active modulation, and record the accurate swelling force during the constant gap testing mode.



## C Application Case - Material Evaluation

### (1) Expansion performance of the formation and charging-discharging processes for different Si/C materials



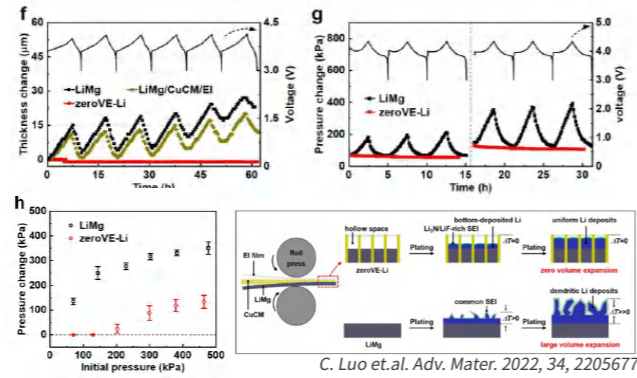
| Information of battery |           |
|------------------------|-----------|
| Item                   | Parameter |
| Normal capacity(Ah)    | 0.2       |
| Cathode material       | NCM811    |
| Anode material         | 450Si/C-  |
|                        | 450mAh/g  |
|                        | 800Si/C-  |
|                        | 800mAh/g  |

The higher the silicon content in the negative electrode, the greater the expansion caused by lithium ions intercalating in the negative electrode to form the Li<sub>x</sub>Si alloy, and it will affect the intercalation phase transition potential of graphite. R&D personnel should reasonably control the ratio of silicon to carbon and modify the structure of silicon-based materials to suppress structural expansion.



## (2) Expansion of Li metal anodes with different modifications

The modified Li metal anode can significantly reduce the volume expansion during cycling!



C. Luo et al. Adv. Mater. 2022, 34, 2205677

## D Application Case-Working Condition Evaluation

### (1) Different Preload

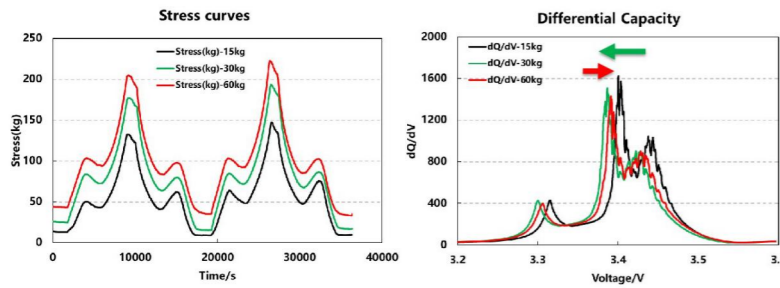


| Pre-stress(kg) | Pre-stress(kPa) | Max Stress(kg)-1st cycle | Max Stress(kPa)-1st cycle |
|----------------|-----------------|--------------------------|---------------------------|
| 15             | 5               | 130                      | 51                        |
| 30             | 10              | 170                      | 67                        |
| 60             | 20              | 200                      | 79                        |

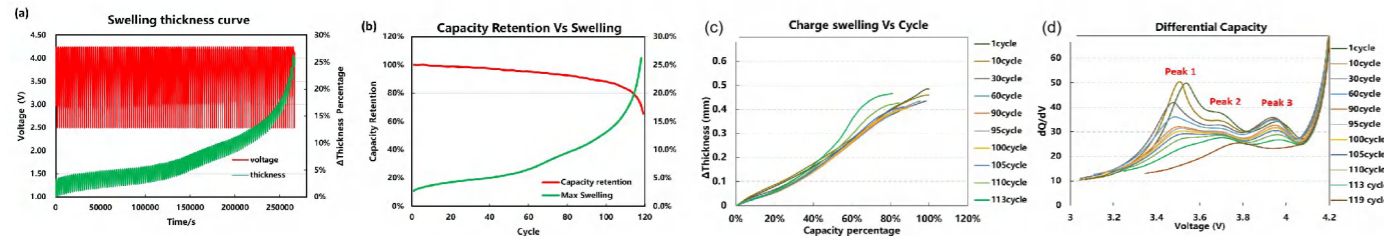
preload (15kg, 30kg, 60kg)  
Hard-shell cell of LFP//Gr.  
(theoretical capacity 100Ah)

With the increase of preload, the initial gap of the cell gradually decreases, and the expansion force during the charging and discharging processes becomes larger. The relationship between the initial preload and the maximum expansion force can be further obtained to help the design of the battery module.

With the increase of the preload, the charge polarization of the battery first decreases and then increases, which shows that for the hard shell battery, a preload of about 30kg is beneficial to increase the rate performance of the battery;



### (2) Cycling Performance

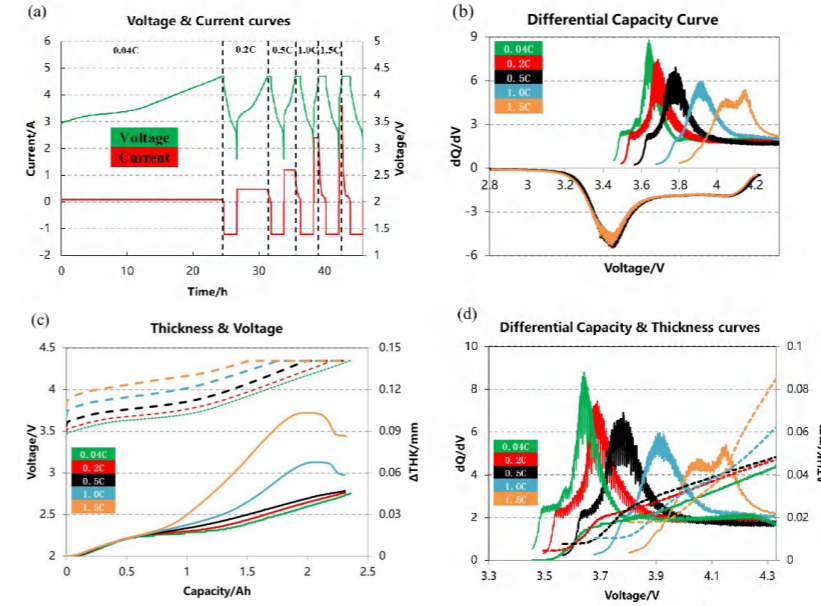


Test Conditions: 25°C 1C 3~4.2V; 50Ah NCM811-Graphite

The relationship between capacity decay and thickness expansion during the long cycling of NCM cells was analyzed. Through the analysis of related expansion thickness and electrochemical data, it can be speculated that the reasons for the capacity decay of NCM cell include electrode mechanical damage, lithium plating and other side reactions.

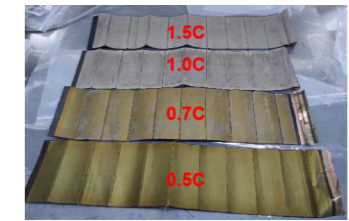
## E Non-destructive lithium plating analysis

### (1) Rate Window

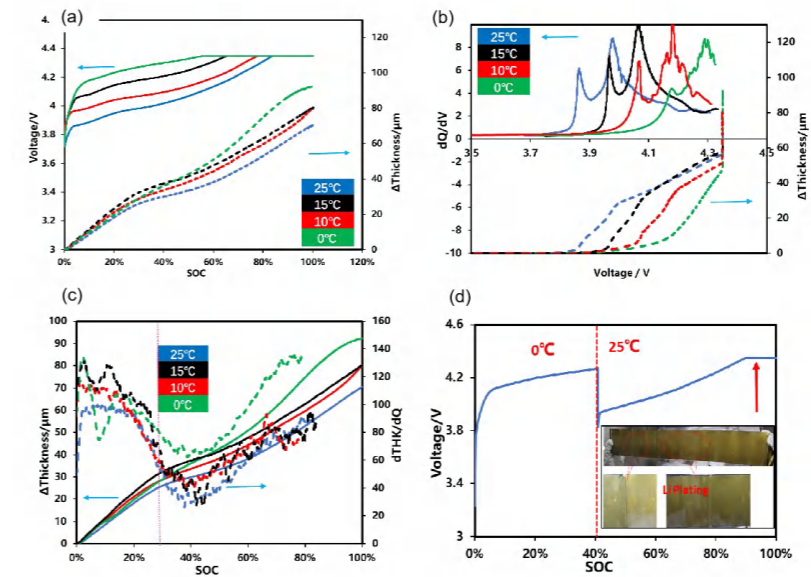


Test method: In situ detect the thickness curves of batteries with different charging rates.

Method of judgment: The thickness curve under a certain charging rate is compared with the thickness curve under a small charging rate which is without lithium plating, and the crotch position can be judged as the rate window of the lithium plating.

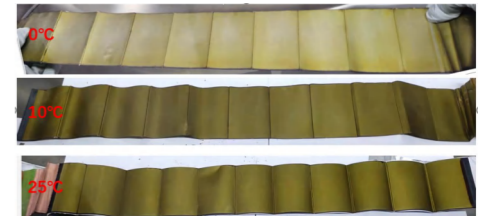


### (2) Temperature Window



Test method: In situ detect the thickness curves of batteries with different temperatures.

Method of judgment: The position where the thickness curve at a certain temperature bifurcates compared with the thickness curve under high temperature which is without lithium plating is the temperature window of the lithium plating.



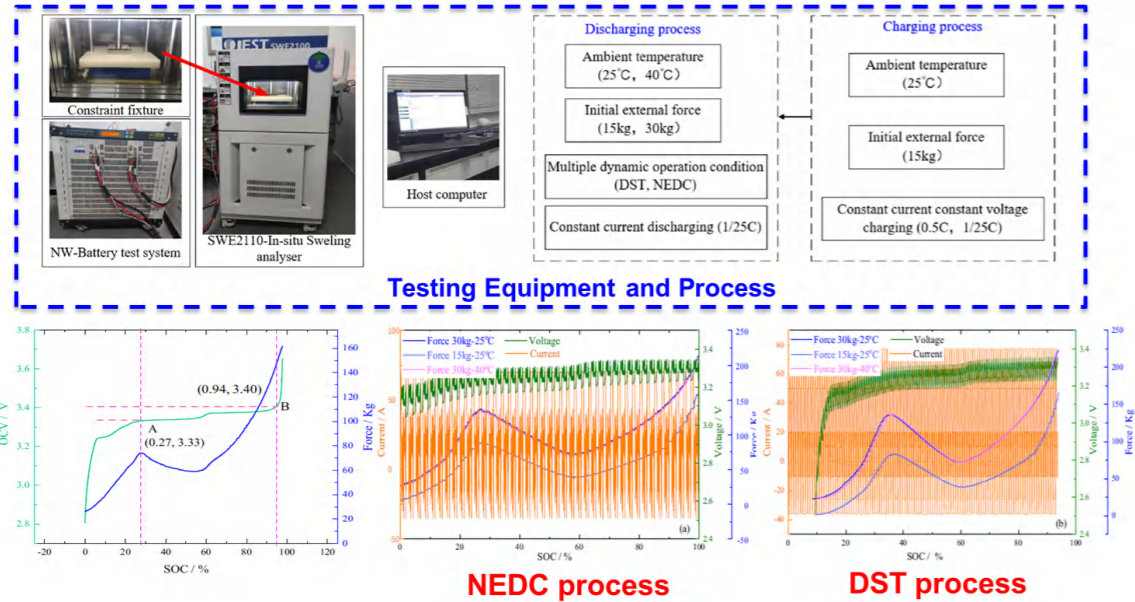
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More cases please pay attention to the Wechat official account of the IEST.

## F Application Case-Hard-shell battery

### (1) SOC estimation based on the expansion force

LFP-Graphite Al-shell

Journal of Energy Storage, 50 (2022) 104559

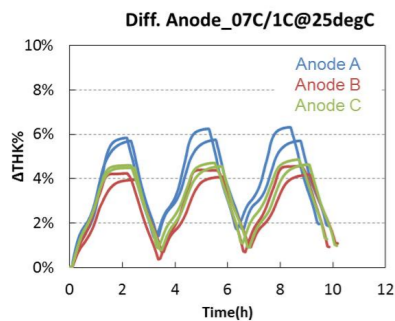


Based on LSSVM and AUKF algorithms, the method of using expansion force to estimate the SOC of LFP battery can achieve an estimation error of less than 1%, which is suitable for different working conditions of temperature, dynamic current and preload.

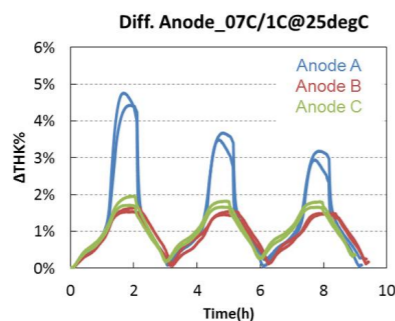
## G Application Case-Cell structure

### (1) M6S Vs SLS Structural comparison

Winding cell expansion



Stacked cell expansion



Two models are used to evaluate the swelling of different anode cells, and the comparison result is almost the same, which is A > C > B.

Because the two sides of the rolled cell are bound, the expansion stress will accumulate to the middle of the cell, which causes the increase of the thickness during the cycling. However, the four sides of the stacked cell are not restricted, so the expansion stress could be released during the cycling (Single-sided anode).

In-situ Swelling data can be used to deeply analyze the influence of the cell structure on stress and strain.

In-situ Swelling can be used to deeply analyze the influence of process on stress and strain.

## Cell Thickness Gauge



Scan QR code for the details



### A Creative Solutions

The cell thickness gauge PPG1000 is a device with high integration, high openness, perfect system function and rapid realization of battery thickness measurement:

1. Return to zero: clear the system error and automatically return to zero;
2. Pressure: free choice of pressure within the range;
3. Thickness calibration block: check the thickness deviation of the measuring system;
4. Controlled by software, it can communicate with MES;
5. Ambient temperature and humidity monitoring: real-time monitoring of chamber ambient temperature and humidity;
6. Sample chamber lamp: the test state of the sample can be clearly seen.

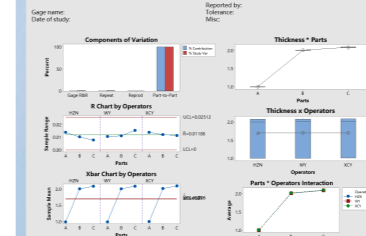
### B GRR Test Data

Gage Evaluation

| Source          | StdDev (SD) | Study Var (6 × SD) | %Study Var (%SV) |
|-----------------|-------------|--------------------|------------------|
| Total Gage R&R  | 0.006255    | 0.03753            | 1.03             |
| Repeatability   | 0.005223    | 0.03134            | 0.86             |
| Reproducibility | 0.003442    | 0.02065            | 0.57             |
| Operators       | 0.003442    | 0.02065            | 0.57             |
| Part-To-Part    | 0.605160    | 3.63096            | 99.99            |
| Total Variation | 0.605192    | 3.63115            | 100.00           |

Number of Distinct Categories = 136

Gage R&R (ANOVA) Report for thickness



| Item                       | Parameter   |
|----------------------------|-------------|
| Thickness test range       | 0~100mm     |
| Thickness test resolution  | 0.001mm     |
| Pressure adjustment range  | 10kg-1000kg |
| Pressure control precision | ±0.3%F.S    |
| Test efficiency            | ≥6ea/min    |

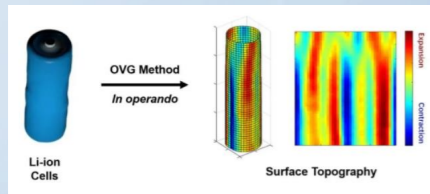
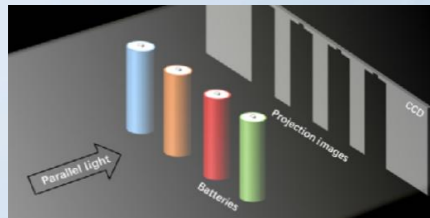
# Cylindrical Battery In-Situ Volume Swelling Testing System



Scan QR code for the details



## A Product Features



- ▶ Optical Imaging + 3D Reconstruction + Real-time Online Monitoring
- ▶ Non-contact, Non-destructive
- ▶ High-throughput testing, suitable for mass production

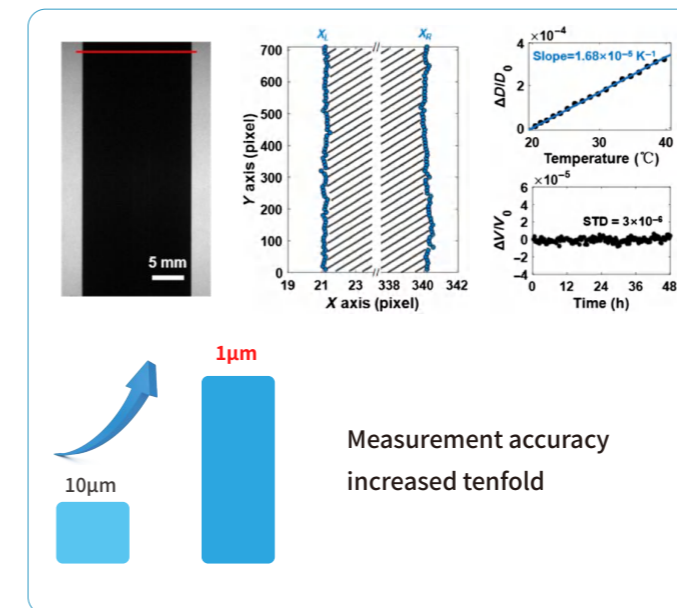
Real time reconstruction of battery surface morphology and calculation of volume deformation during charge and discharge processes. Combining voltage and current data to detect and predict battery health condition from a higher dimension.

## B Model Specifications Table

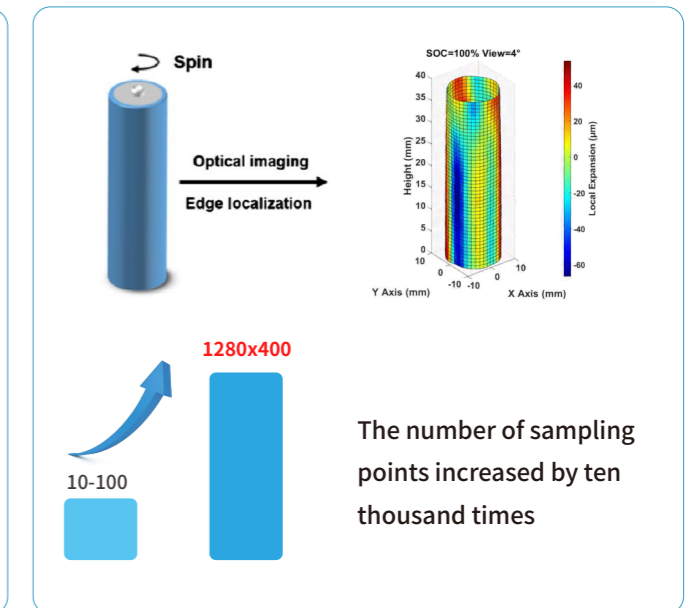
| CCS1300-4        |                |                              |                            |        |                |
|------------------|----------------|------------------------------|----------------------------|--------|----------------|
| Compatible Cell  | Channel Number | Optical Detection Resolution | Optical Detection Accuracy | Weight | Size(W×D×H)    |
| Cylindrical Cell | 4              | 0.1μm                        | ±1μm                       | 50kg   | 500x230x360 mm |

## C Leading Technology

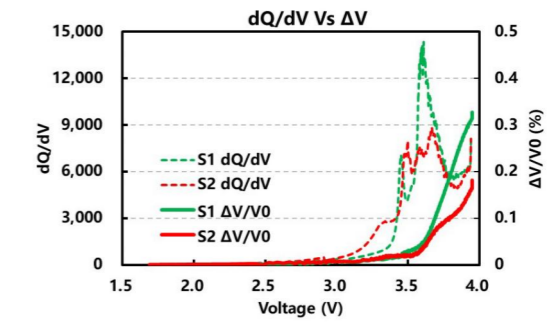
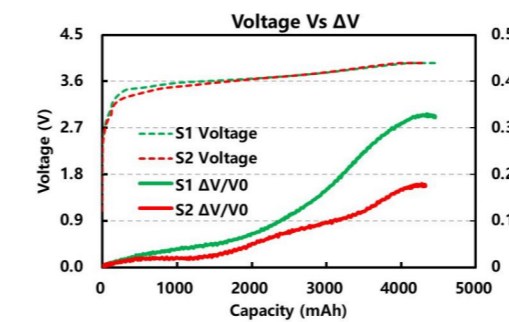
### High-precision Detection Technology



### Rotational 3D Reconstruction Technology



## D Application Case



21700 Cell parameters: Sample 1-15%SiC ; Sample 2-10%SiC

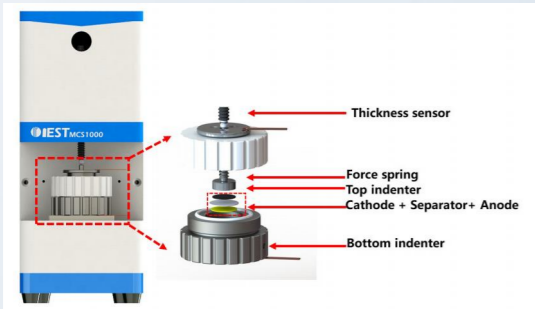
The volume swelling curve during formation shows that as the silicon content increases, the volume swelling during formation process increases, and the peak corresponding to lithium intercalation on the differential capacity curve becomes higher.

# Model Coin-cell Swelling System



Scan QR code for the details

## A Test Principle And Application Direction



**Test principle:** The model coin cell is assembled in a sealed mold to in-situ test the expansion thickness of coin cell during the charging and discharging processes.

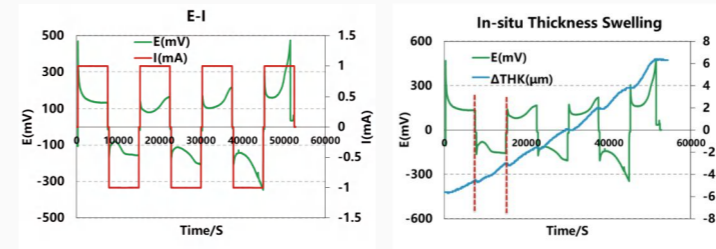
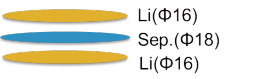
**Applications:**  
 Li-Li symmetrical cell  
 LCO/NCM/LFP-Li half-cell  
 NCM-Graphite full coin cell  
 NCM-Si/C full coin cell  
 All-solid-state battery

## B Model parameter

| Model   |                         | Parameter                 |        |
|---|-------------------------|---------------------------|--------|
| MCS1000 (single channel)  | MCS1400 (four channels) | Thickness measuring range | 0-10mm |
| Die diameter: 13mm, 16mm, 20mm (Other sizes can be customized)  |                         | Thickness resolution      | 0.1μm  |
| Note:IEST is committed to continuous improvement of our products. If there is a technical modification, we will not notify you otherwise!Thank you for understanding. |                         | Thickness accuracy        | ±1μm   |

## C Application Case

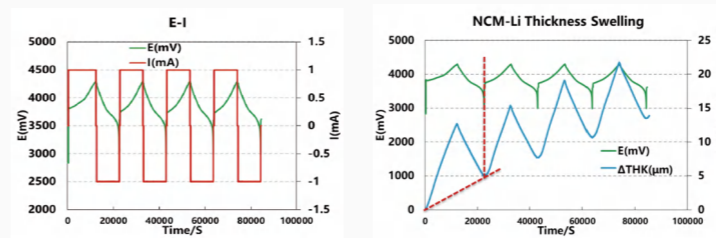
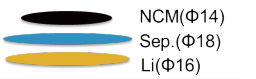
### (1) Li-Li cell



Assemble Li-Li symmetric cell to test the thickness change during lithium deposition; test parameters: Current density is 0.5mA / cm<sup>2</sup>, charging and discharging for 2h and rest for 5min;

During the lithium deposition, the total thickness of the cell gradually increased. Every 2 mAh of the lithium deposition will cause the increase of the thickness of about 2 μm, corresponding to the volume expansion of about 0.76 mm<sup>3</sup>/mAh.

### (2) NCM-Li cell

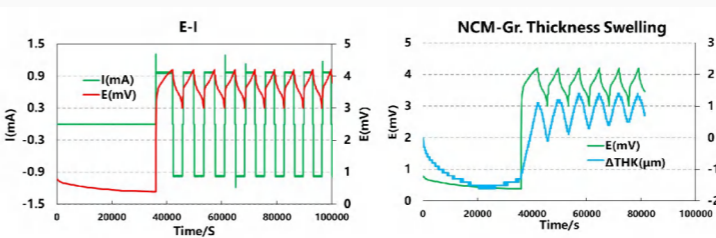


Assemble the NCM-Li half cell to test the thickness change during charging and discharging; test parameters: the current density is 0.6mA / cm<sup>2</sup>, 3~4.3V;

During the charging process, the thickness expansion is about 4 μm/mAh, and the volume expansion is about (0.6 mm<sup>3</sup>/mAh), which is mainly caused by the lithium plating at the surface of the lithium metal anode;

During the discharging process, the thickness shrinkage is about 3 μm/mAh, and the volume shrinkage is about (0.5mm<sup>3</sup>/mAh), which is mainly due to the decrease of the thickness of the lithium metal anode caused by the continuous deintercalation of the lithium ions from the lithium metal anode.

### (3) NCM-Graphite Cell

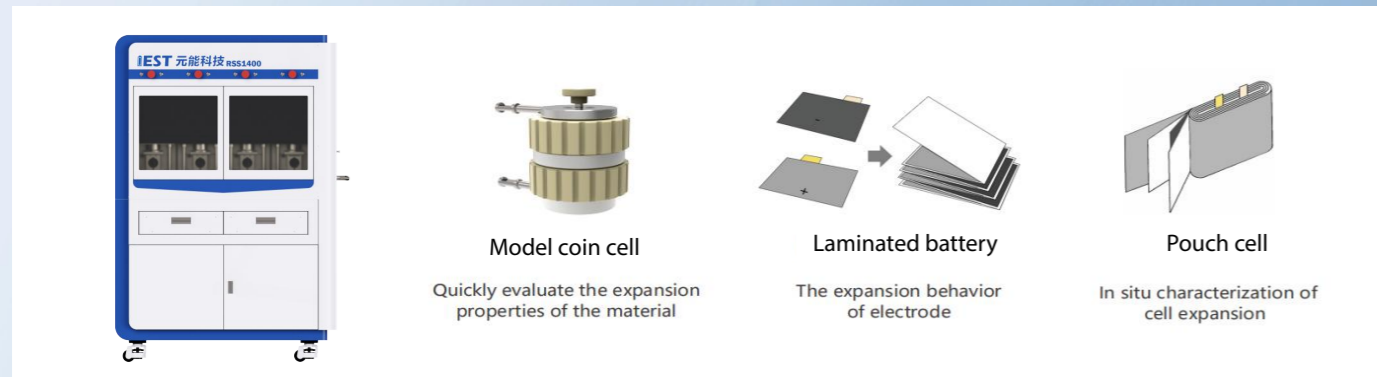


Assemble NCM-Si / C LIB and test the thickness change during charge and discharge; Test parameters: current density is 0.6mA / cm<sup>2</sup>, 3~4.3V;

Ignore the expansion of NCM positive electrode, and the total expansion thickness measured from the model coin cell mainly comes from the expansion of the SiC negative electrode during the expansion experiment. By further deducting the thickness of the copper current collector, the thickness expansion ratio can be calculated;

Compared with two kinds of materials, expansion ratio of A material is greater than that of B material. The expansion ratios of these two materials at the first charging process are similar. During the subsequent cycling, the maximum expansion thickness of B material will decrease compared to the first cycle, and shows increase gradually during the cycling. However, for the A material, the maximum expansion thickness of each cycle increase continuously. These different expansion behaviors between these two materials are due to the different modification ways.

# In Situ Rapid Swelling Screening For Silicon-Based Anode



## A Main Features

1. In-situ characterization of the expansion thickness change of the silicon based system.
2. Four channels for testing multiple cells simultaneously.
3. Suitable for cells with various structures: model coin cell, stacked cell and pouch cell, etc.
4. Visual operation interface, one click to export the data.



Scan QR code for the details

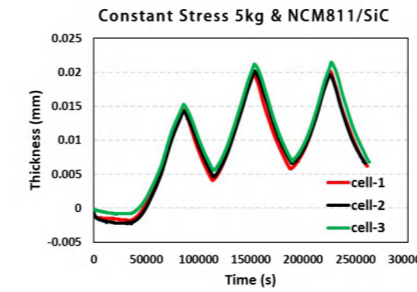
## B Differences between different models of RSS series

| Model                                    | RSS1100  | RSS1200       | RSS1300          | RSS1400       |
|--|--|---------------|------------------|---------------|
| Number of channels                       | 4  |               | 4                |               |
| Pressure regulation mode                 | with weight  |               | with servo motor |               |
| Pressure range                           | 0.5kg/1kg/5kg<br>(Can be customized according to specific needs) |               | 1~100kg          |               |
| Pressure accuracy/resolution             | ±0.01kg  |               | 0.1kg/±0.3%F.S.  |               |
| Scope of thickness detection             | ±5mm   | ±5mm          | ±5mm             | ±5mm          |
| Thickness detection resolution/precision | 0.1μm/±1μm   | 0.01μm/±0.1μm | 0.1μm/±1μm       | 0.01μm/±0.1μm |
| Systematic error                         | ≤3%  | ≤3%           | ≤3%              | ≤3%           |
| Maximum cell size                        | 60*90*4mm (Can be customized according to specific needs)        |               |                  |               |

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## C Application Case

### (1) In-Situ expansion test of model coin cell



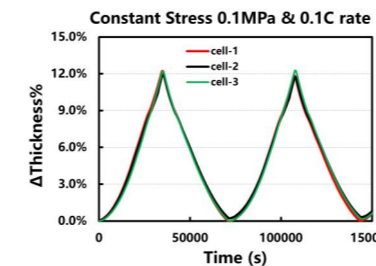
| No.    | charge Q/mAh | Thickness /mm |
|--------|--------------|---------------|
| cell-1 | 3.13         | 0.0157        |
| cell-2 | 3.07         | 0.0155        |
| cell-3 | 3.11         | 0.0155        |
| mean   | 3.10         | 0.0156        |
| sigma  | 0.025        | 9.43E-05      |
| COV    | 0.8%         | 0.6%          |

**Cell Parameters:**  
Full coin cell(NCM811 / SiC), with the capacity of about 3 mAh.  
**Experimental parameters:**  
Three parallel samples, charging and discharging for three cycles, and synchronously record the expansion thickness of these three full coin cells.

The full coin cell expands / shrinks with the charge / discharge process, and the turning point of the voltage curve in the three cycles is highly consistent with the turning point of the thickness expansion curve, indicating that the expansion thickness curve can effectively reflect the volume change of the electrodes caused by the intercalation / deintercalation of lithium-ions. The average of the relative expansion thickness was about 0.0156mm and the COV of the expansion thickness was only 0.6%, indicating the good cycle consistency of the model coin cell.

Note: COV (Coefficient of Variation) = (standard deviation, sigma) / (mean)

### (2) In-Situ expansion test of multi-layer laminated cells

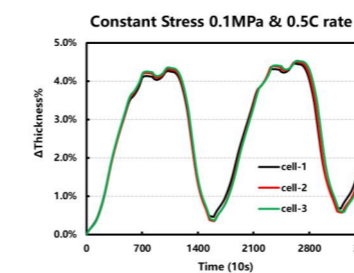


| No.    | charge Q/mAh | charge swelling/% |
|--------|--------------|-------------------|
| cell-1 | 371.2        | 12.5%             |
| cell-2 | 371.6        | 12.1%             |
| cell-3 | 374.1        | 12.2%             |
| mean   | 372.30       | 12.3%             |
| sigma  | 1.283        | 0.002             |
| COV    | 0.3%         | 1.4%              |

**Cell Parameters:**  
Multi-layer stacked cell (NCM811 / SiC), with a capacity of about 400 mAh;  
**Experimental parameters:**  
Three parallel samples, synchronously test the thickness expansion ratio at a constant pressure of 0.1MPa.

The multilayer stacked cell expands / contracts with the charge / discharge process, and the thickness expansion curves of three parallel samples maintain good repeatability for both two cycles. The maximum expansion ratio is about 12.5%, and the expansion thickness COV of three parallel samples is 1.4%, indicating a good consistency between the parallel samples.

### (3) In-situ expansion test of the pouch cell

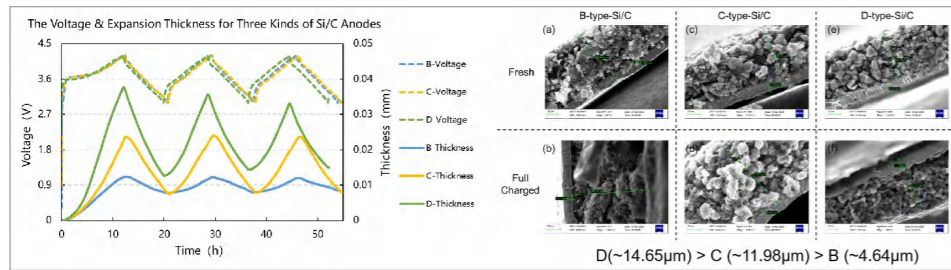


| No.    | charge Q/mAh | charge swelling/% |
|--------|--------------|-------------------|
| cell-1 | 4416.7       | 4.1%              |
| cell-2 | 4445.4       | 4.2%              |
| cell-3 | 4439.3       | 4.3%              |
| mean   | 4433.8       | 4.2%              |
| sigma  | 12.345       | 0.001             |
| COV    | 0.3%         | 1.9%              |

**Cell Parameters:**  
Multi-layer pouch cell with winding structure (NCM811 / SiC), capacity of about 400 mAh;  
**Experimental parameters:**  
Three parallel samples, synchronously test the thickness expansion ratio at a constant pressure of 0.1MPa.

The multi-layer pouch cell expands/contracts with the charging/discharging process, and the thickness expansion curves of three parallel samples maintain good repeatability for both two cycles. When the pouch cell is fully charged, the corresponding maximum expansion ratio is about 4.3%, and the expansion thickness COV between the three groups of batteries is 1.9%, indicating that the consistency among these three parallel samples.

## (4) Expansion of Si/C anodes with different modifications

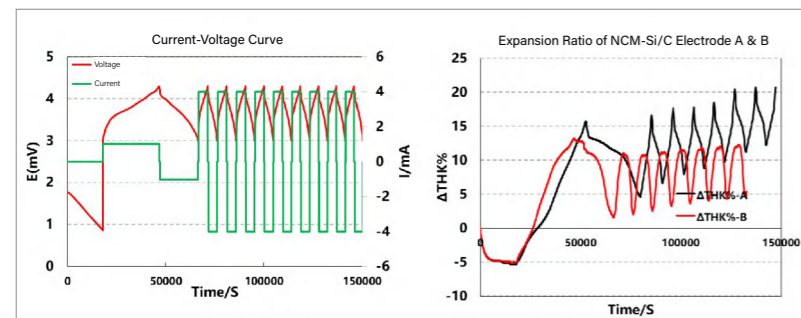


Assemble NCM-Si/C batteries, and compare the expansion differences of different modified Si/C anodes;



Negative electrode: B, C, and D Si/C materials have similar capacity (~5.9mAh), but they are made by different modification methods (among them, material B is a low-expansion Si/C material specially modified by a battery material company in Ningbo, China); Fix the same positive electrode material and compare the expansion of the three Si/C negative electrodes. It can be seen that the specially modified Si/C material of type B has the smallest expansion; The expansion thickness of the three is consistent with the trend of the measurement results under the electron microscope;

## (5) Cycling for NCM-Si/C cell with different modifications



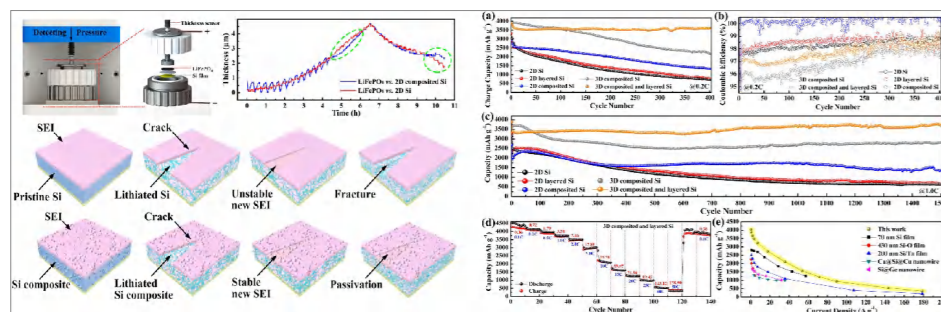
Assemble the NCM-Si/C coin cells, and test the thickness change during charging and discharging; Test parameters: current density is 0.6mA/cm<sup>2</sup>, 3~4.3V;

When testing the thickness expansion of the model coin cell, we ignore the expansion of the positive NCM electrode, and the measured total expansion mainly comes from the Si/C negative electrode. After deducting the thickness of the copper foil, the expansion ratio can be calculated;

Comparing these two materials, the expansion ratio of material A is generally greater than that of B, and when the first cycle is fully charged, the difference between these two materials is small. When the subsequent cycle continues, the maximum expansion thickness of B will decrease compared with the first cycle, and the subsequent maximum expansion thickness increases slightly. However, for the material A, the maximum expansion thickness of each circle increases dramatically, which may be related to the difference in the modification methods of these two Si/C materials.

## (6) Expansion for a new-type Si/C anode

J. Lin et al. Angew. Chem. Int. Ed. 2023, 62, e202216557



Research and development of high-capacity, low-expansion silicon-based anode materials;

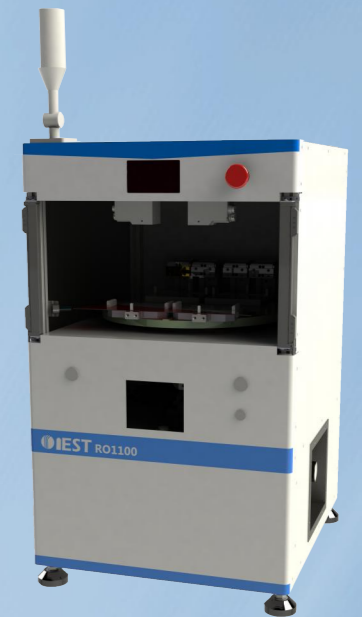
By introducing a "bulk phase passivator" to stabilize the interface of the silicon anode, a new silicon-based anode material with ultra-high specific capacity and low expansion is obtained!

The coated "3D composite silicon" has higher coulombic efficiency, excellent reversible capacity and good cycle performance, which is due to the "bulk phase passivation mechanism"; The in-situ expansion test of "3D composite silicon" was carried out by using a model coin cell. It can be seen that the "bulk phase passivation mechanism" can effectively alleviate the volume expansion ratio of the silicon negative electrode without reducing the reversible capacity.

# Automatic Voltage Resistance Tester



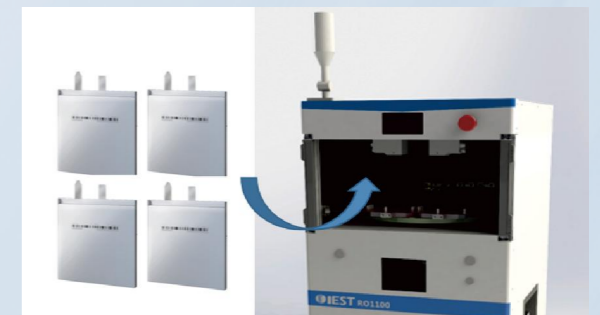
Scan QR code for the details



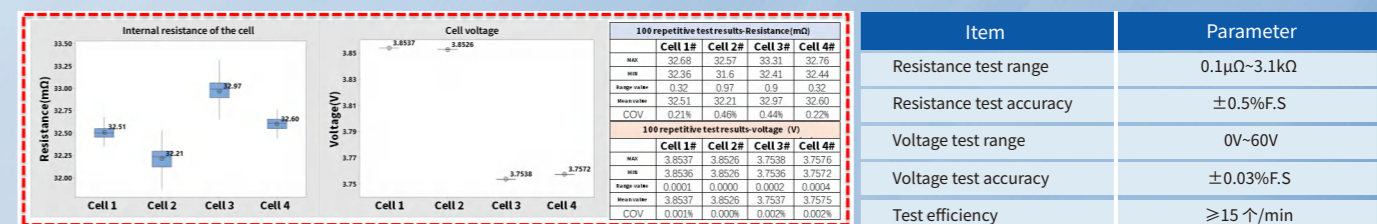
## A Creative Solutions

RO1100 automatic battery voltage resistance tester is a device with high integration, high openness, perfect system function, minimize human intervention, rapid realization of battery voltage resistance measurement. The advantages as following:

1. The equipment has four channels, can be a single continuous test of 2 cells;
2. The contact force of the test clip is fixed, the contact resistance is fixed, and the measured resistance fluctuation is small;
3. Can test two cells at a time, high test efficiency, can test more than 15EA in a minute;
4. Plane contact, with little damage to the polar ear;
5. Automatic scan code cell, automatically test the voltage internal resistance data and save;
6. Automatic software can set the voltage specification range, beyond the specification of automatic alarm;



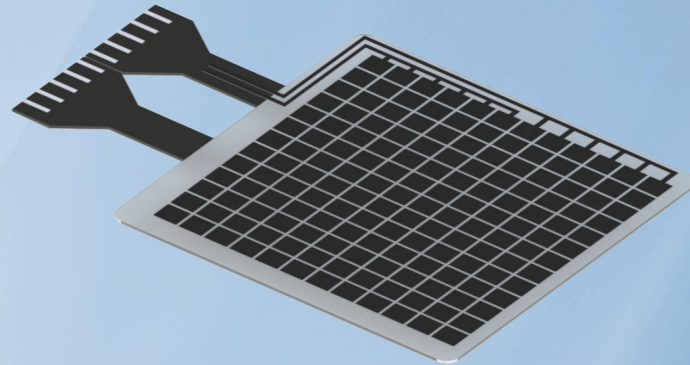
## B Test Result



# Battery Pressure Distribution Measurement System



Scan QR code for the details

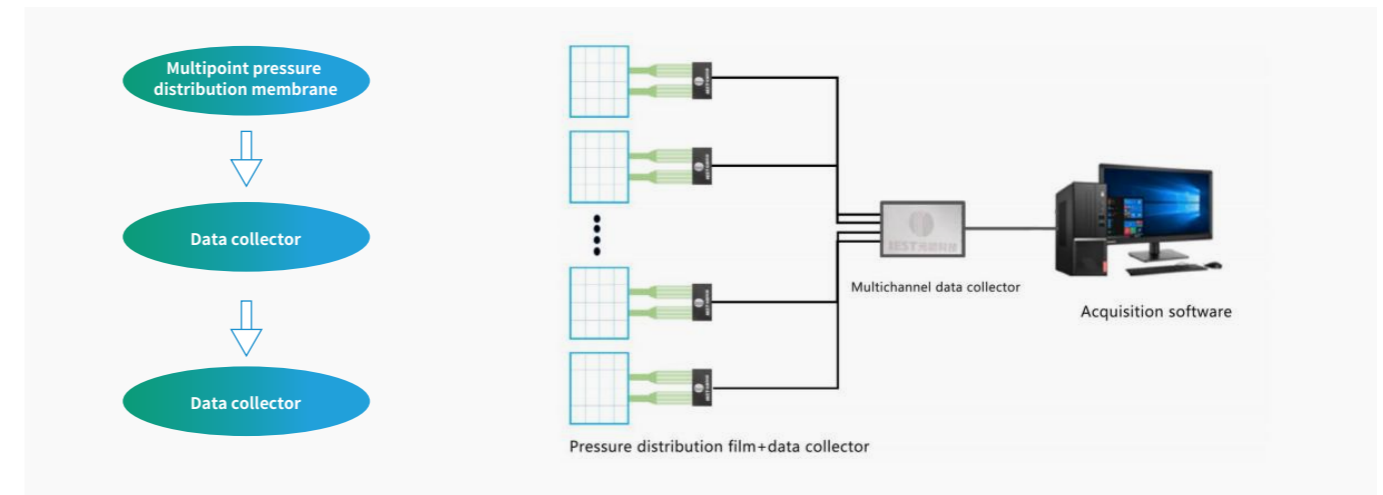


## A Model Parameter

| Model                             | BPD1000   |
|-----------------------------------|---|
| Sensor film size                  | 160*160mm (Can be customized according to customer needs)                                   |
| Pressure range of sensing unit    | 0~30kg(0~5MPa)  |
| Pressure accuracy of sensing unit | ±10% FS   |
| Sensing unit size                 | 7.5*7.5mm   |
| Sensor thickness                  | <0.3mm  |
| Number of sensors                 | 16X16 array layout, 256 sensors in total<br>(Can be customized according to customer needs) |
| Data collector                    | 1 (Sampling frequency<10Hz) , size about 20*80*120mm(Height * width * length)               |
| Software                          | 1 set   |

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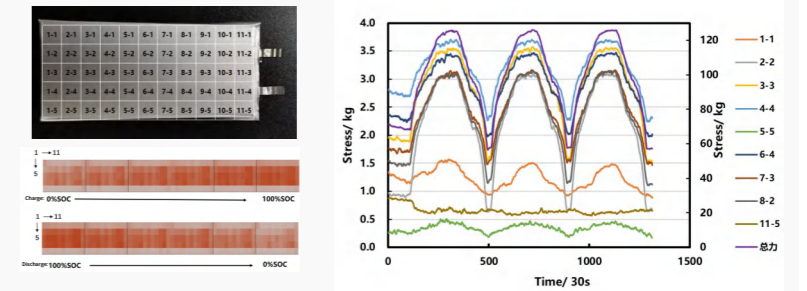
## B Can support multi-channel integration



## C Application Case

### (1) Test of stress distribution on the surface of the cell during the cycle

**Test information:** NCM-Graphite system, 3~4.3V, 0.5C, 50kg preload;  
**Result analysis:** It can quantitatively characterize the difference of stress distribution on the surface of the cell, provide a deeper perspective for the stress analysis of the cell, and help technicians analyze the stress distribution in the cell, explore the causes of failure of the cell, and develop a safer and more reliable cell.



### (2) Surface flatness test of fresh cell

| Information of cell |          |         |         |
|---------------------|----------|---------|---------|
|                     | Cell1    | Cell2   | Cell3   |
| Cathode             | NCM      | LCO     | LFP     |
| Anode               | Graphite |         |         |
| Capacity            | 2000mAh  | 4800mAh | 3000mAh |
| Model               | 345877   | 456494  | 5778125 |
| SOC                 | 50%      |         |         |

**Result analysis:** there is a certain correlation between the cell process design and the cell pressure distribution (flatness). Technicians can develop appropriate distribution standards through the pressure distribution system to monitor the batch stability of the delivered cells.

# Electrolyte Wetting Measurement System



Electrolyte capillary wetting system



Electrolyte weight immersion system

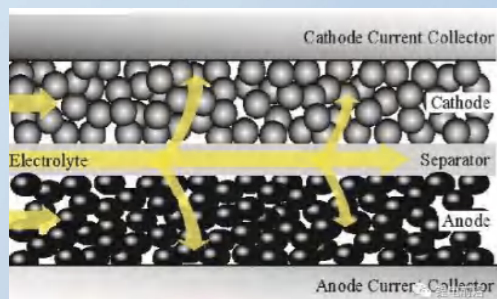


Electrolyte Height Immersion System

## A Application

- Electrolyte performance evaluation
- Electrode consistency assessment
- Optimization of material/ electrode surface treatment processes

## B Principle of electrode wetting



EFFECT OF electrode compression on the Wettability of Lithium-ion Batteries

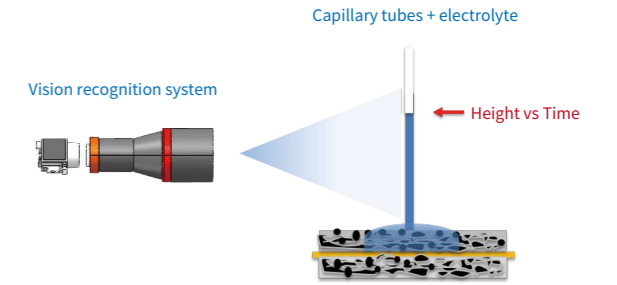
The Lucas-Washburn infiltration model is commonly used to describe the dynamic of liquid absorption in electrode pores, as represented by the equation below. Here, ( h ) denotes the liquid absorption height, ( t ) stands for absorption time, ( c ) represents the shape factor for different pore capillaries, ( r ) refers to the capillary radius, ( cr ) is a constant termed as the form radius, ( θ ) stands for the liquid surface tension, and ( η ) denotes the liquid viscosity.

$$h^2 = \frac{cr \cos \theta}{2\eta} t$$

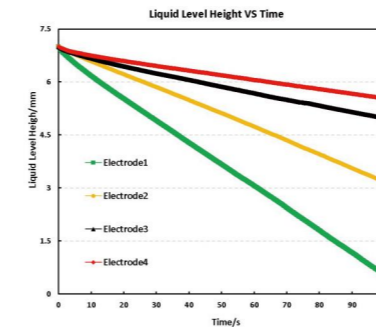
## C Electrode electrolyte capillary wetting system

### (1) Key Features

1. Equipped with a high-precision vision testing system for stable and efficient testing repeatability.
2. In-situ real-time characterization of electrolyte wetting rate on negative electrode sheets of lithium-ion batteries.
3. Applicable Samples: Negative electrode sheets.
4. The greater the compaction of the electrode sheet, the lower the porosity, resulting in poorer electrolyte wetting.



### (2) Application Case



Comparison of liquid absorption heights for negative electrode sheets with different compaction densities.

Four different compaction densities of electrode sheets: 1 (1.35g/cm<sup>3</sup>) < 2 (1.5 g/cm<sup>3</sup>) < 3 (1.6 g/cm<sup>3</sup>) < 4 (1.65 g/cm<sup>3</sup>)

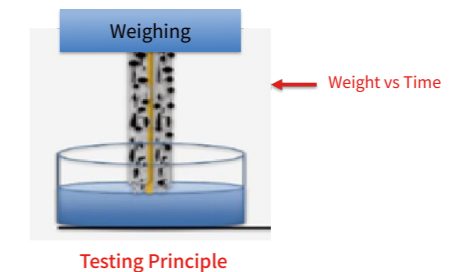
### (3) Model and Parameters

| EWS1100                        |                |
|--------------------------------|----------------|
| Pressure control range         | 0~500g         |
| Pressure resolution / Accuracy | 0.01g/±0.3%F.S |
| Single-pixel precision         | 10μm           |
| Liquid absorption capacity     | 2μL            |
| Electrode dimensions           | 29*29mm        |

## D Electrode electrolyte weight immersion system

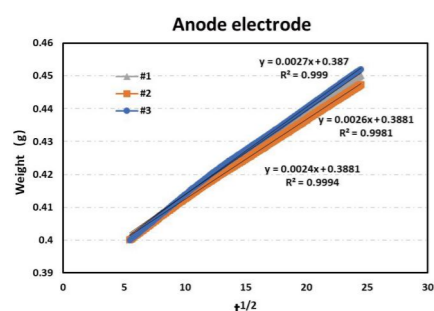
### (1) sheets of lithium-ion batteries

1. Equipped with a high-precision weighing system for stable and efficient testing repeatability.
2. In-situ real-time characterization of electrolyte wetting rate on positive and negative electrode sheets of lithium-ion batteries.
3. Test Samples: Positive electrode sheets, negative electrode sheets.
4. Good overlap among the three sets of electrode sheets, indicating good consistency in electrolyte wetting.





## (2) Application Case



Trimming three sets of negative electrode sheets from the same batch (65\*70mm)

## (3) Model and Parameters

| ETS1100           |                    |
|-------------------|--------------------|
| Balance capacity  | 0~220g             |
| Balance precision | $\pm 0.1\text{mg}$ |
| Electrode size    | 65*70mm            |

## KEY CUSTOMERS

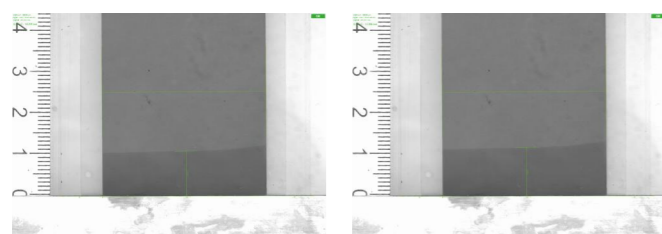
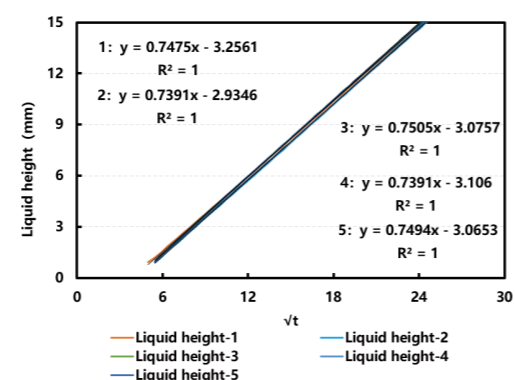
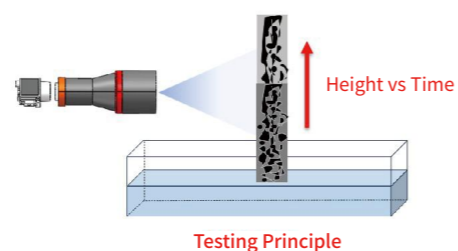
More than 2,000 pcs (sets) of equipments have been provided, serving more than 400 lithium battery users at home and abroad!

Distributed in material companies, battery companies, terminal companies, university research institutes and government testing units

## E Electrode Electrolyte Height Immersion System

### (1) Key Features

1. Equipped with a high-precision vision acquisition system for stable and efficient testing repeatability.
2. In-situ real-time characterization of electrolyte wetting rate on positive and negative electrode sheets of lithium-ion batteries.
3. Test Samples: Positive electrodes, negative electrodes.
4. Capable of simultaneous testing of 3 parallel samples, exhibiting good consistency in electrolyte wetting.



### (2) Model and Parameters

| CHT 1000        |                   |
|-----------------|-------------------|
| Testing time    | 15min             |
| Pixel precision | 100 $\mu\text{m}$ |
| Electrode size  | 240*40mm          |

### Customers:

