DEDICATED TO LITHIUM-ION BATTERY TESTING AND DEVELOPMENT

IEST®

INNOVATIVE LITHIUM ION BATTERY TESTING SOLUTION PROVIDER

PRODUCT CATALOGUE

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IEST 3 Major Business

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

IEST Linkedin

www.iestbattery.com

Initial Energy Science&Technology Co.,Ltd

COMPANY INTRODUCTION

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!

CATALOGUE

Contents

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； 2.Pressure：70MPa； 3.Resistance range：1μΩ~20MΩ Remarks: National Standard for Graphite Negative Materials：GB／T 24533-2019，Stress Required 2200lb			1.Die diameter：16mm； 2.Pressure：200MPa； 3.Resistance range: 1μΩ~1200MΩ	1. Die diameter：16mm； 2.Pressure：200MPa； 3.Resistance Range：1μΩ~200MΩ	
Testable Parameters	◆Single point test ◆Continuous test ◆Variable pressure model ◆Pressure relief mode ◆ Powder resistance, resistivity, conductivity, powder thickness, powder compaction density under constant pressure conditions ◆ Powder resistance, resistivity, conductivity, powder thickness, powder compaction density under different pressure conditions ◆ Relationship curve of powder resistance, resistivity, conductivity and powder compaction density ◆Automatic measurement software					
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 (≤200MPa) 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.

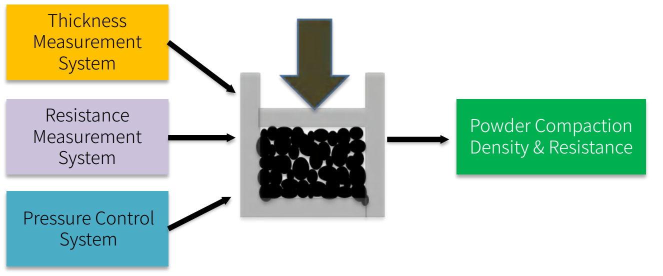
Calculation formula

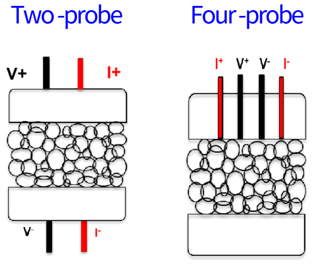
Compaction Density(g/cm^3)： $D = \frac{m}{S*L}$

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

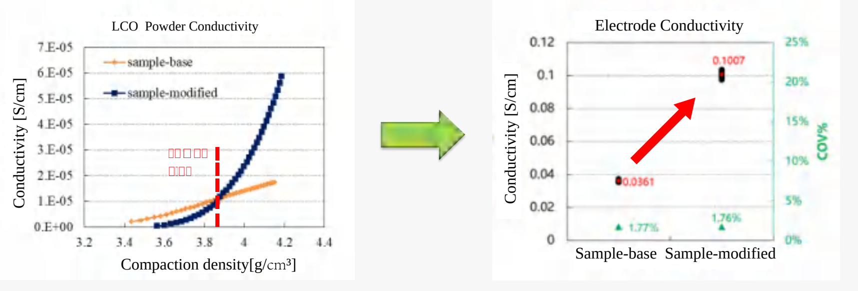
Conductivity (S/m)： $\sigma_e = \frac{1}{\rho} = \frac{l}{RS}$

Resistivity(Ω*cm)-PRCD2100： $\rho = k\frac{U}{I}$ (Where k 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 4.0g/cm^3.

Result analysis：

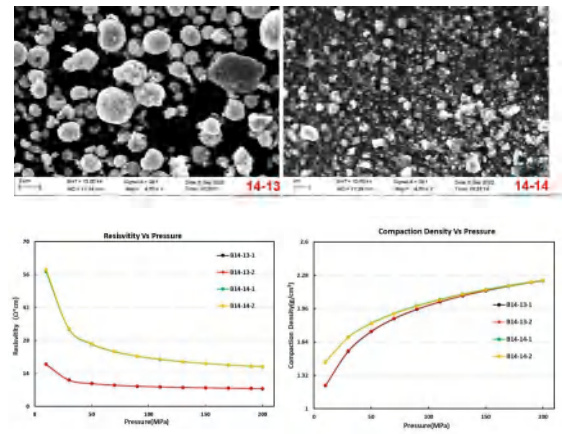
For modified powder samples, when the compaction is less than ~3.87g/cm^3 (pressure <75MPa), the conductivity is lower than that before modification; however, when the compaction is greater than ~3.87g/cm^3 (pressure>75MPa), the electrical conductivity of the modified powder is better than that before 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.

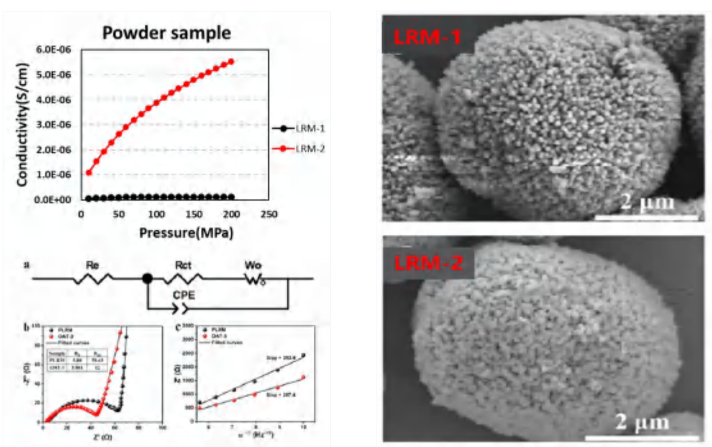
D Application Case

(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.



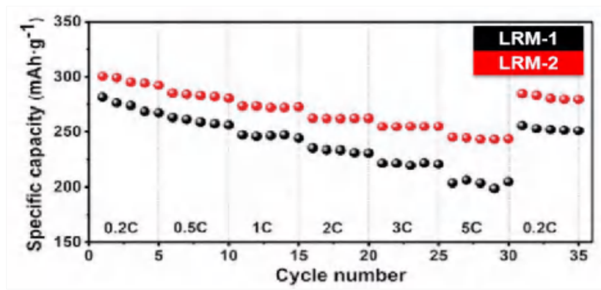
(2) Lithium-rich materials



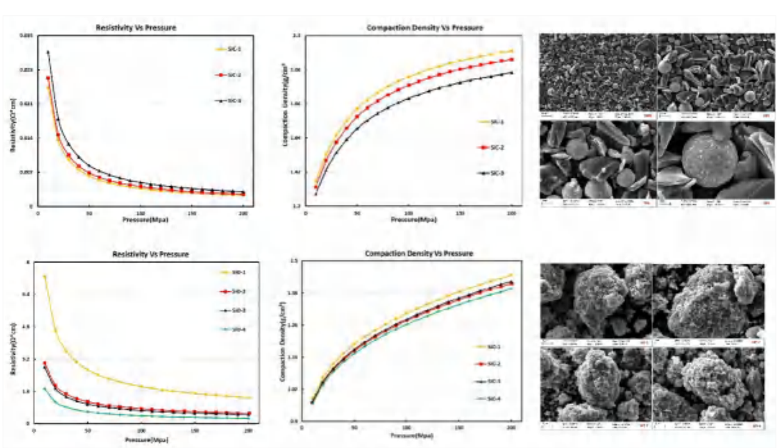
W.B. Guo et.al. Adv. Mater. 2021, 33, 2103173

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.



(3) Silicon-based materials

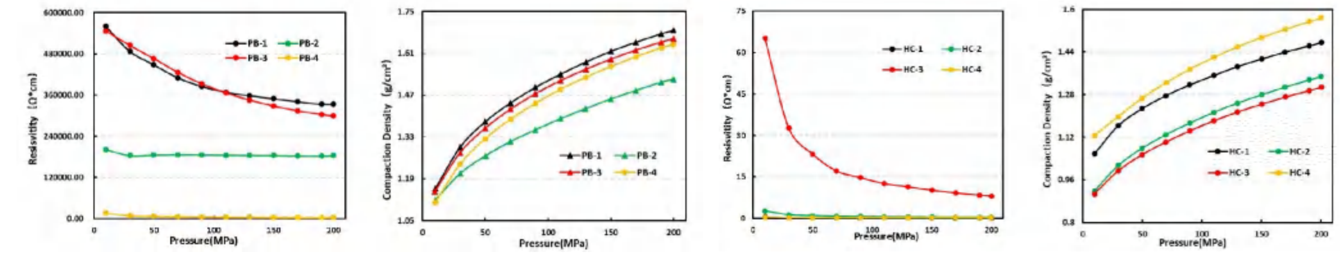


SiC-The Si content is 3%, 6% and 10%, respectively.

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.

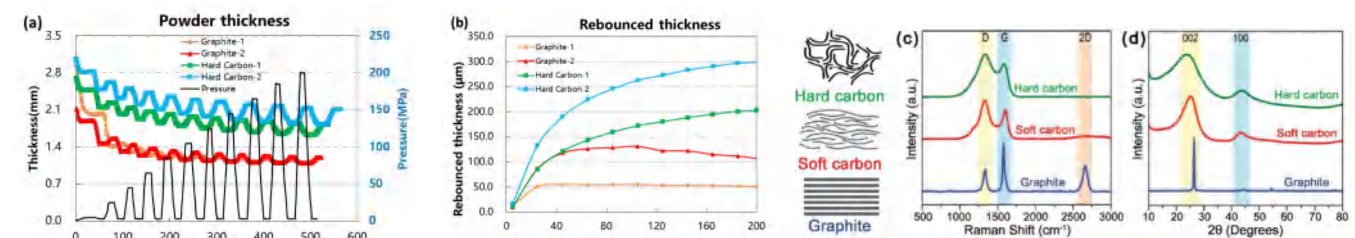
SiO-Material sintering temperature:SiO-1<SiO-2<SiO-3<SiO-4

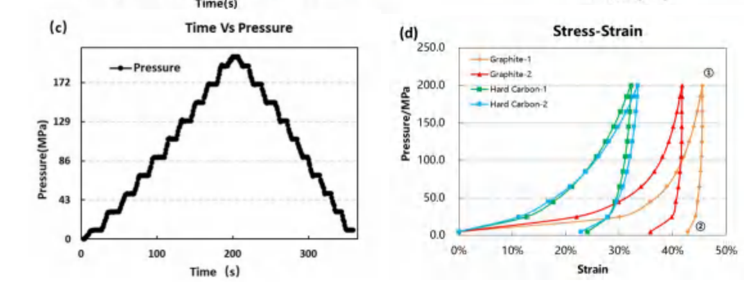
(4) Positive and Negative Materials for Sodium ion battery



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





Name	Reversible Deformation	Irreversible Deformation	Max Deformation
Graphite-1	2%	43%	45%
Graphite-2	6%	36%	42%
Hard Carbon-1	8%	24%	32%
Hard Carbon-2	10%	23%	33%

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

Mold for testing

Automatic demolding instrument

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

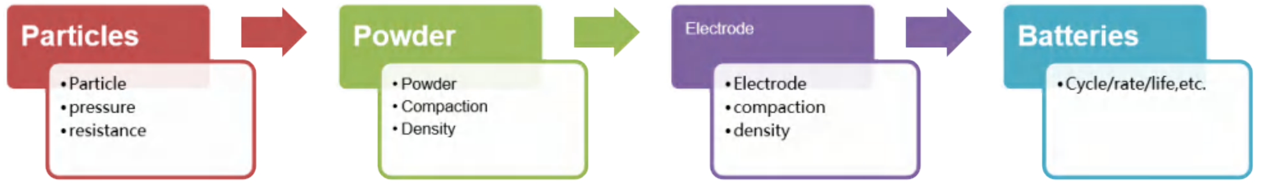
Scan QR code for the details

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	•	•

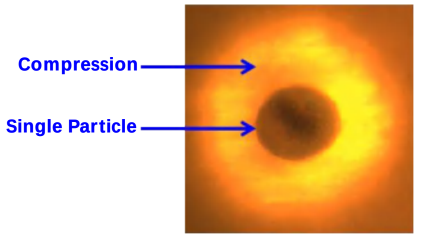
B Product Introduction

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.

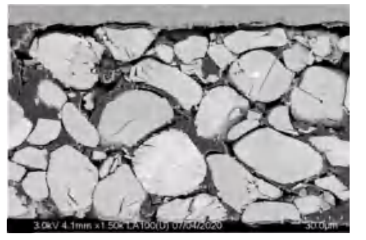


Testing Object：Lithium battery positive and negative electrode materials(Positive : polycrystalline ternary, lithium-rich material; Negative: silicon-based, hard carbon, etc.; solid electrolyte)

Test Particle Size：single particle size: 5~50 um

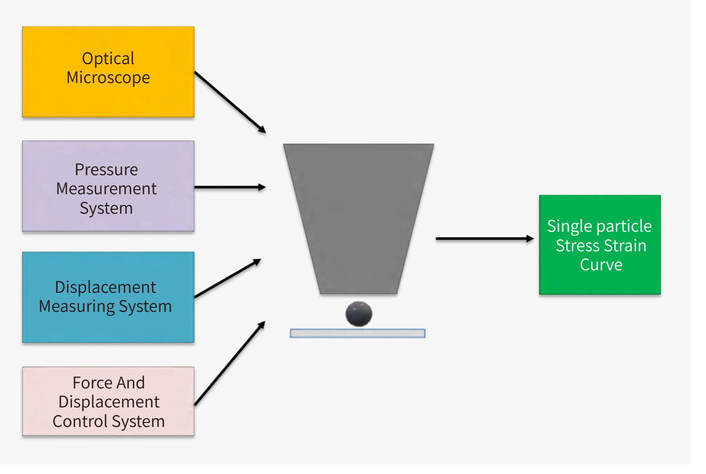


Single Particle Compression (Bottom View)



Cracking after Particle Circulation (SEM Image)

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.

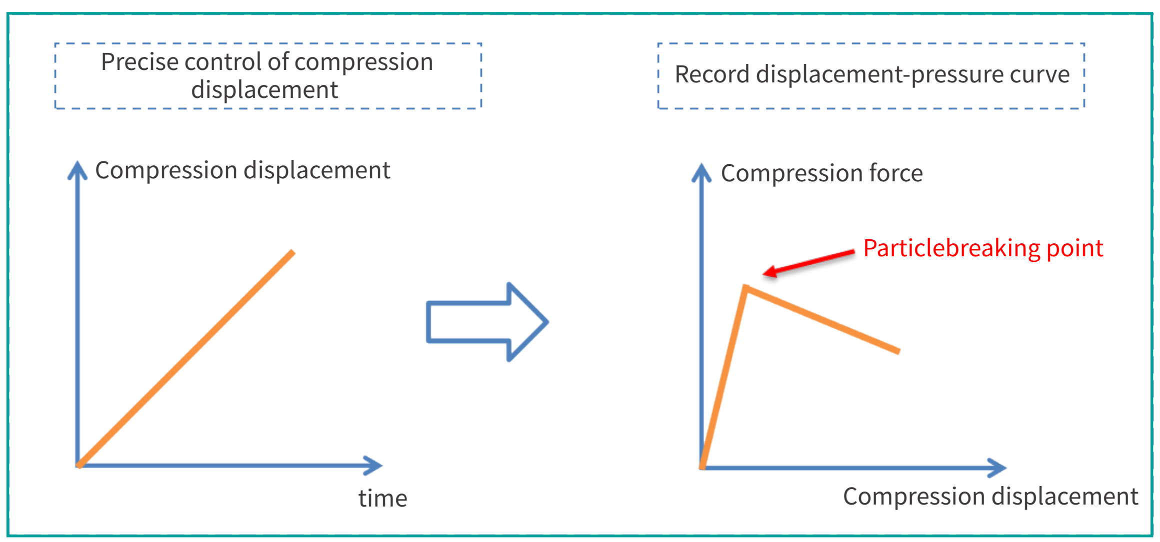
Structural Functional Dversification	Diverse Testing Modes	Fully Automated Software	Customized for Lithium-ion Batteries	High cost-performance ratio
• High-resolution optical imaging • Displacement precision control • Optical system inverted design • XY automated displace-ment platform	• Displacement control mode • Pressure control mode • Fatigue testing mode	• Real-time display of force displacement curve • One-click data analysis • Real-time observation and logging. Particle crushing process.	• Cathode material • Anode material • Precursor material • Solid electrolyte materials	• With the same functionalities, the price is much lower than similar instruments abroad.

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.

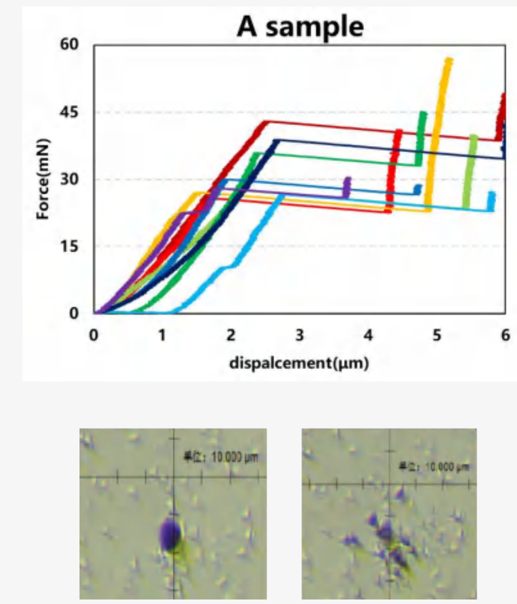
Test Parameters:
Magnification: up to 1200 times;
Pressure test range: 0-100 mN;
Pressure test accuracy: ±0.1 mN;
Minimum displacement unit: 10nm;
Data collection frequency 1000HZ;

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

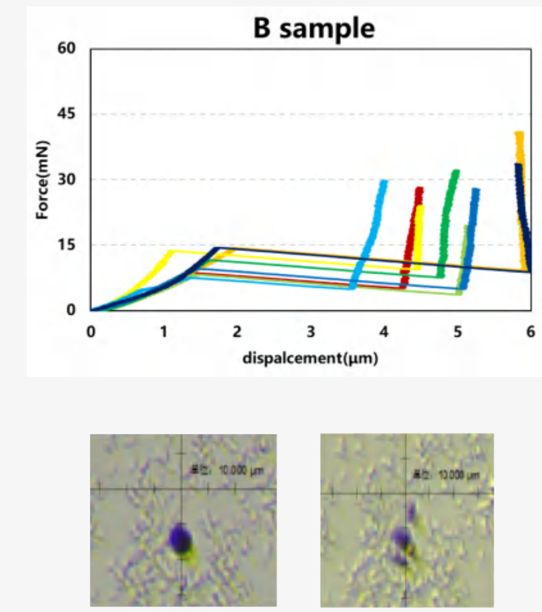


D Application Case

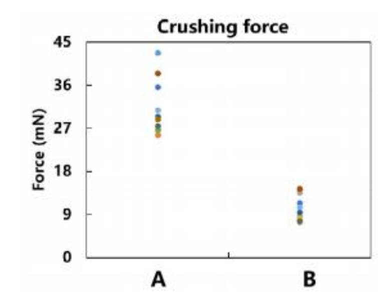
Anode Material——SiC



Before Crushing　After Crushing

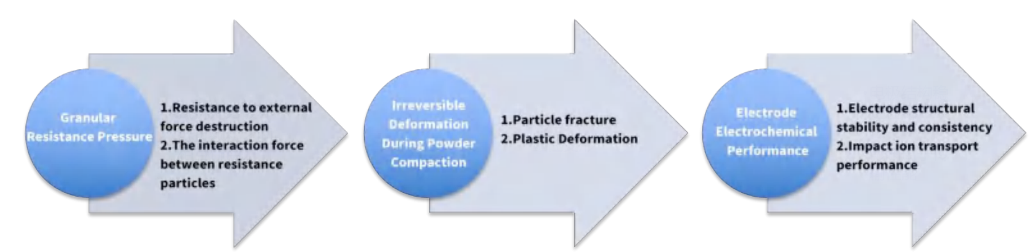


Before Crushing　After Crushing



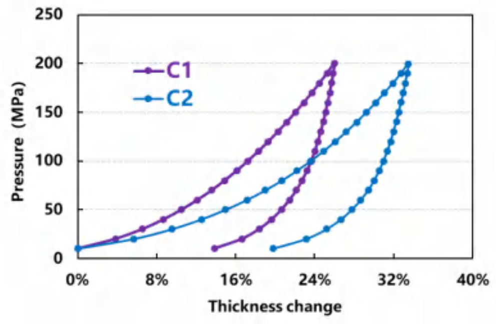
1. Two silicon-carbon materials with different electrode compaction;
2. Comparison of crushing force distribution: A>B.
3. Analysis of stress-displacement curves: Sample A exhibits initial micro-cracking followed by complete collapse, while sample B experiences direct structural collapse and fragmentation.
4. Comparison of Disintegration States: After fracturing, all three groups disintegrate into fine granular states.

Particle Compression Resistance and Powder Compaction

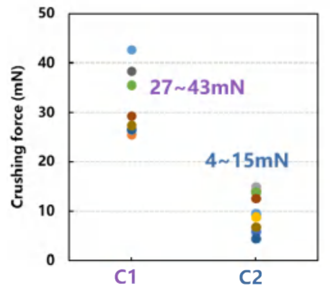


Case 1: Two Different Pure Carbons

Powder Compression Deformation



Single Particle Crushing Force

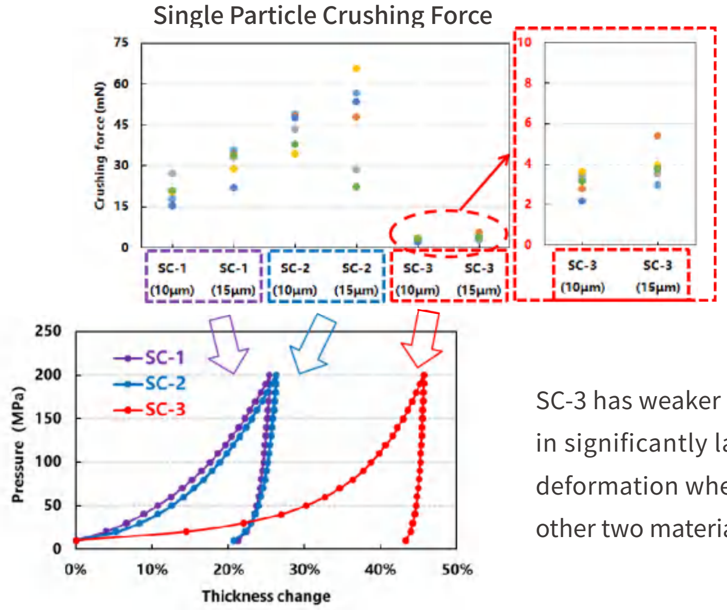


Material	Irreversible Deformation Parameter	Maximum Deformation Value
C1	13.8%	26.0%
C2	19.8%	33.5%

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



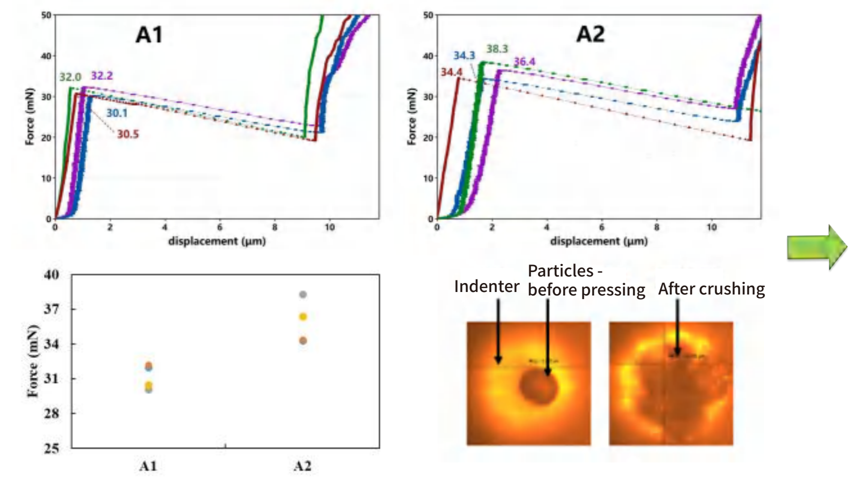
Powder Compression Deformation

Materia	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.

Ternary Cathode Material——NCM811

Case 1

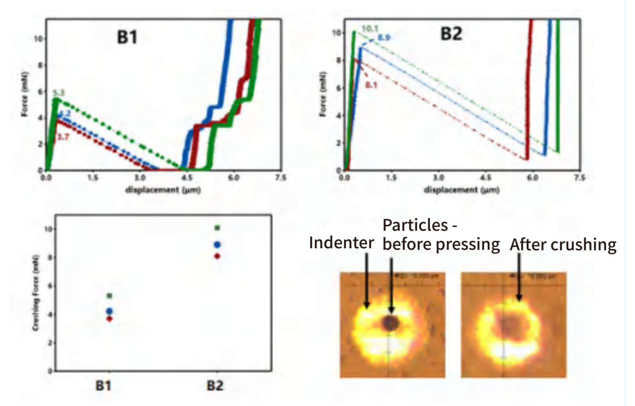


1. Two ternary materials A1 and A2 are sintered from the same precursor, but the sintering process is different. The particle size D50 is 18 μm.

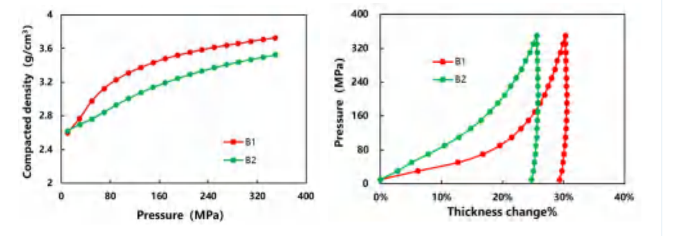
2. The compression resistance of A2 is better than that of A1, and changing the sintering process can improve the material hardness to a certain extent. Single particle mechanical property characterization methods can provide guidance for the sintering process of materials.

Case 2

Single Particle Testing

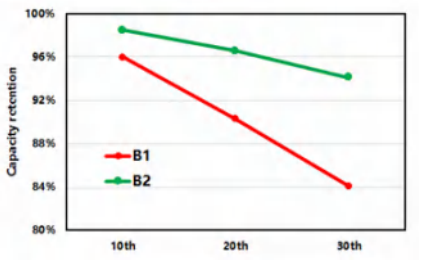


Powder Testing



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.

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.

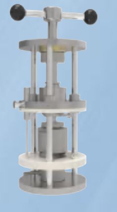
Highly-Precision Testing System For Solid Electrolyte

Scan QR code
for the details

A Creative Solutions

IEST 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



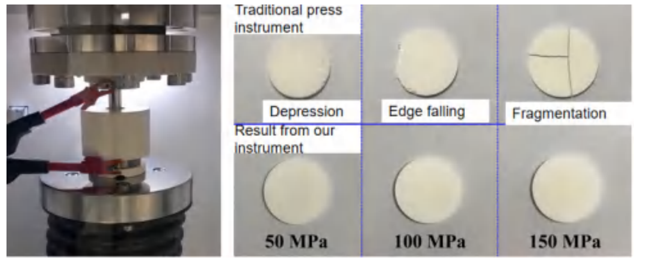
SEMS1000

SEMS1100

B Application Case

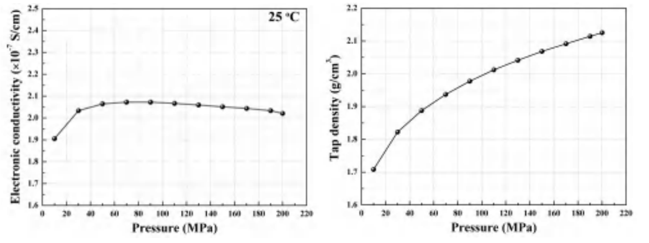
(1) Powder production

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.



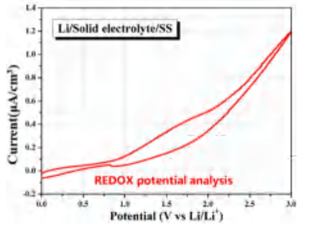
(2) Electronic Conductivity & Compacted Density

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

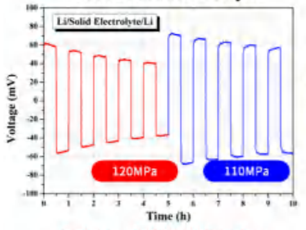
Through the cyclic voltammetry (CV) module of SEMS, it is possible to analyze the electrochemical stability window of solid electrolyte under different pressure.



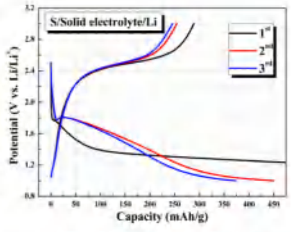
(4) Solid-state battery cycling performance

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.

LIPSCI Solid Electrolyte



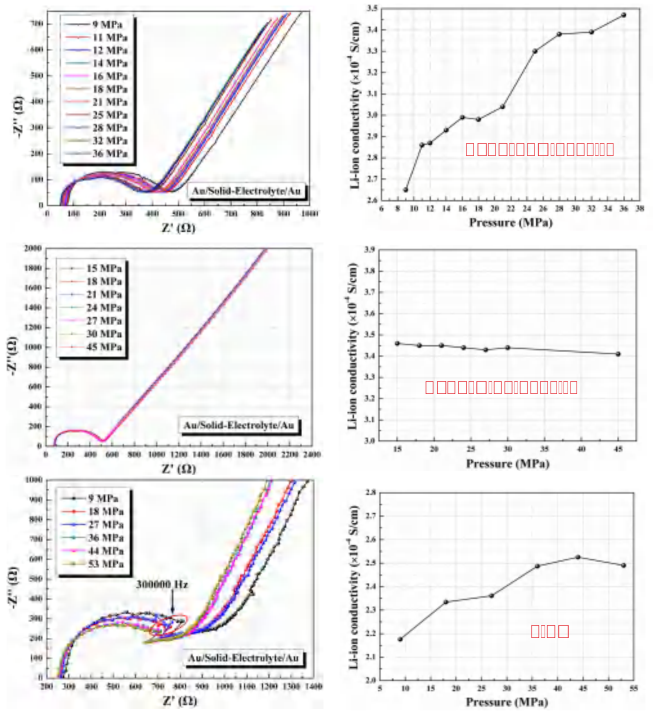
Stability of Li/SE/Li interface under different pressures



All-solid lithium metal battery

(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.



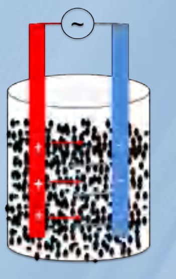
Battery Slurry Resistance Analyzer

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;



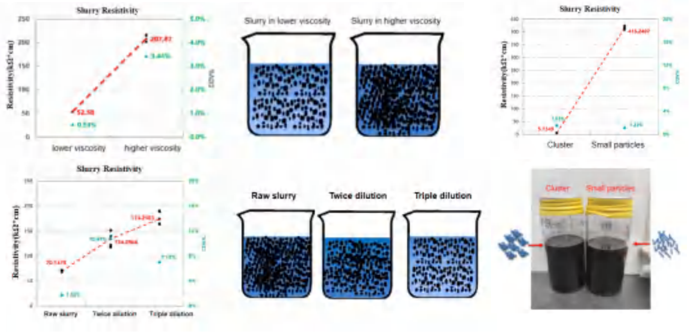
Resistivity (Ω*cm)： $\rho_e = \frac{U}{I} \times \frac{S}{l}$

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℃	Temperature accuracy/resolution	±0.5℃/0.1℃
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

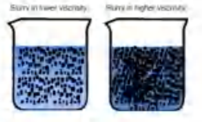


When the viscosity, concentration and dispersant type of the conductive agent are changed, the resistivity also changes!

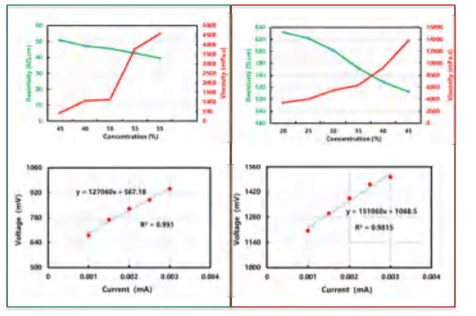
In the future, specifications can be formulated for the slurry resistivity of a certain fixed viscosity, and the stability of the slurry process can be monitored!

(2) Concentration-Viscosity-Resistivity Correlation

Slurry formula



Graphite	SP	CMC	SBR
96.5	0.5	1.5	1.5
LCO	SP	CNT	PVDF
94.0	2.0	1.0	3.0

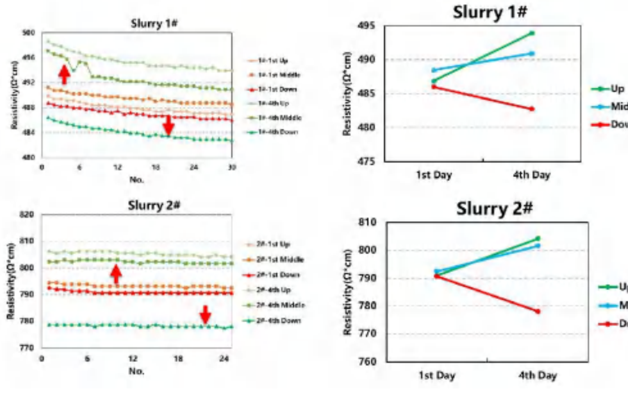


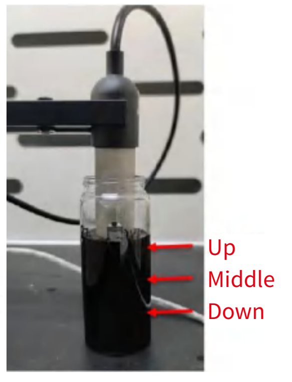
LCO Slurry　　Graphite Slurry

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 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 eletrode, 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;

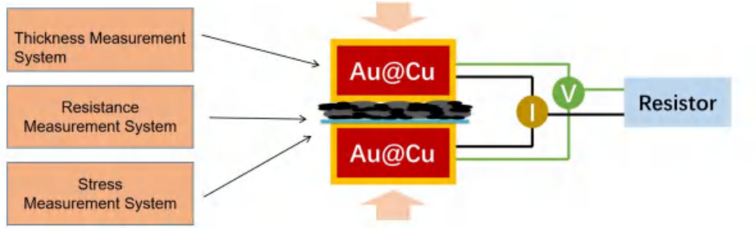
3.Equipped with standard resistance block and thickness block measured by a third-party metrology institute.

Calculation formula:

Compaction Density(g/cm³): $D = \frac{m_{\text{Area density}}}{L_{\text{Coating Thickness}}}$

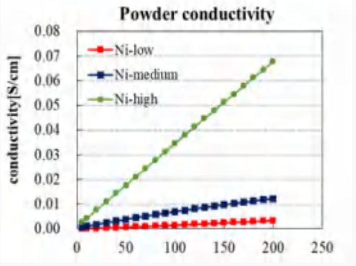
Resistance(Ohm): $R = \rho \frac{l}{s}$

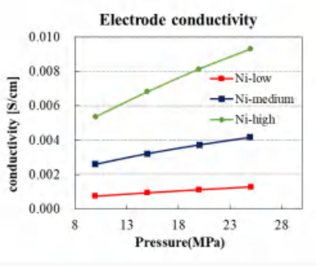
Conductivity (S/m): $\sigma_e = \frac{1}{\rho} = \frac{l}{RS}$



C Appliction-Material Evaluation

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





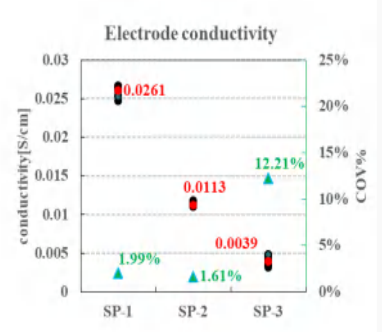
Result analysis:

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:

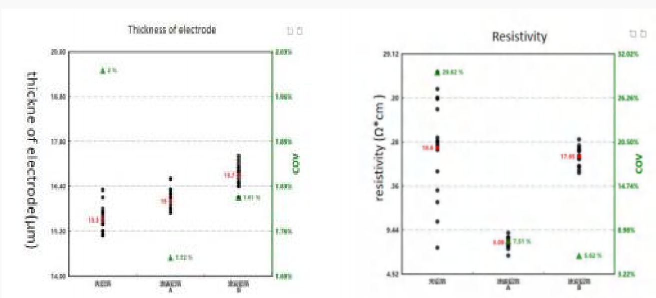
①Compared with the conductivity of three conductive agents, SP-1>SP-2>SP-3;

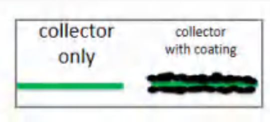
②Compared with the dispersibility of three conductive agents, the COV value of SP-3 is largest which means that the dispersion uniformity of SP-3 is poorest; the dispersibility of SP-1 and SP-2 is better;

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



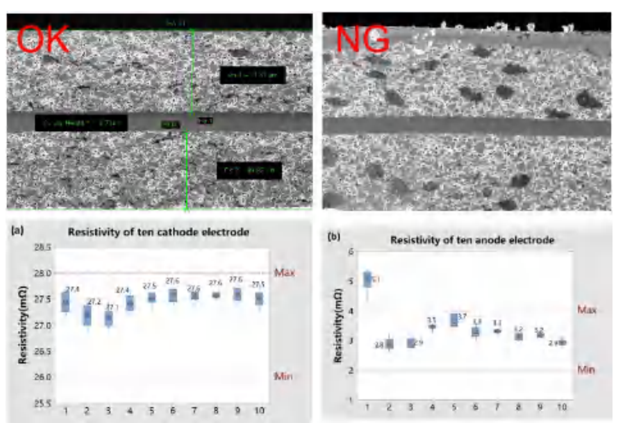


Constant pressure:
25MPa, hold pressure for 15s and collect 10points;

Result analysis:
①Different primer coating processes will change the conductivity of the current collector;
②After coating 1~2μm primer material on the aluminum foil, the conductivity uniformity of the current collector is better;

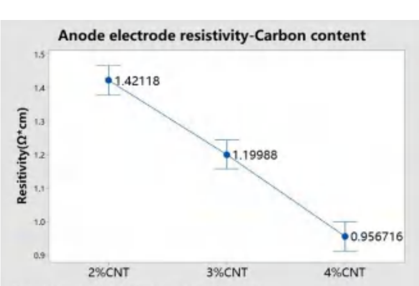
D Application Case - Process Evaluation

(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



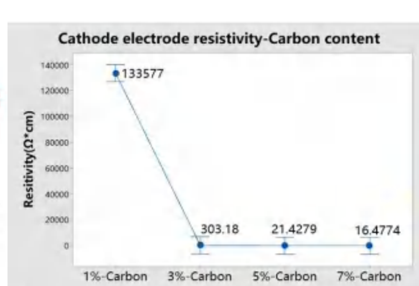
Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	2	0.64767	0.323833	132.59	0.000
Error	15	0.03664	0.002442		
Total	17	0.68430			

Means

Factor	N	Mean	StDev	95% CI
2%CNT	6	1.4212	0.0609	(1.3782, 1.4642)
3%CNT	6	1.1999	0.0472	(1.1569, 1.2429)
4%CNT	6	0.9567	0.0373	(0.9137, 0.9997)

Pooled StDev = 0.0494210



Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	3	80156878491	26718959497	425.77	0.000
Error	20	1255087802	62754390		
Total	23	81411966293			

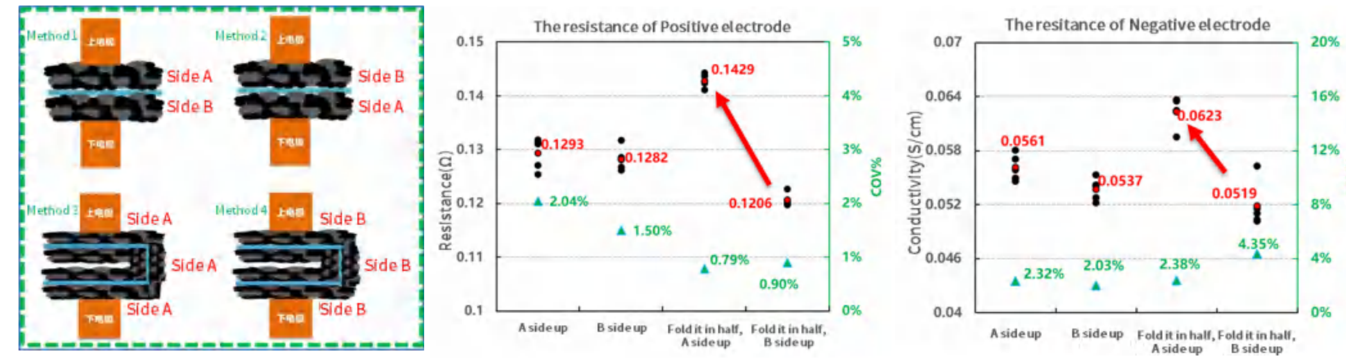
Means

Factor	N	Mean	StDev	95% CI
1%-Carbon	6	133577	15843	(126831, 140324)
3%-Carbon	6	303.2	38.2	(-6442.9, 7049.3)
5%-Carbon	6	21.43	2.54	(-6724.68, 6767.53)
7%-Carbon	6	16.48	2.99	(-6729.63, 6762.58)

Pooled StDev = 7921.77

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



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

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

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

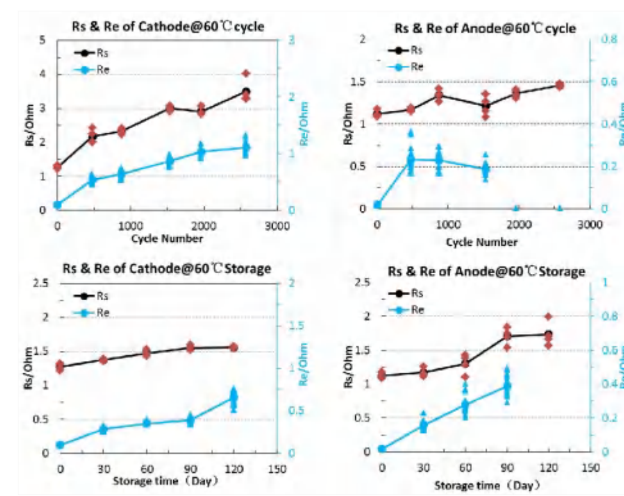
④ $R_{Total} = R_{B\text{-Upper electrode}} + 2R_B + 2R_{B\text{- Foil material}} + R_{\text{Foil material}} + R_{B\text{- Lower electrode}}$

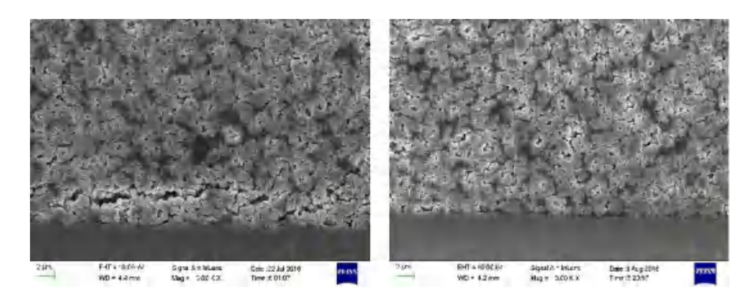
Test parameters: 25MPa test pressure, hold pressure for 15s, and test 5 parallel points for each group;

Result analysis:
①When the A side or the B side is facing up alone, the difference in the resistance and uniformity of the electrode sheet is small;
②The 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	◆ Testing of separator ionic conductivity and electrode MacMullin number under different pressures. ◆ The software interface displays test curves and allows for fitting of EIS curves to obtain parameters such as ionic conductivity and MacMullin number.		◆ Automatic ventilation to ensure a high-purity argon gas environment inside the chamber. ◆ Automatic liquid injection ◆ Assemble multi-channel symmetric batteries rapidly and test EIS. ◆ The software interface displays test curves and can fit the EIS curve to obtain parameters such as ion conductivity and MacMullin number.	

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

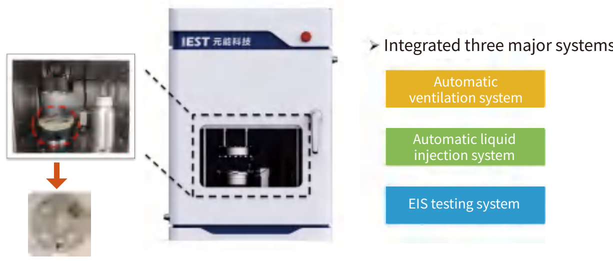
B Creative Solution One

◆ 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.

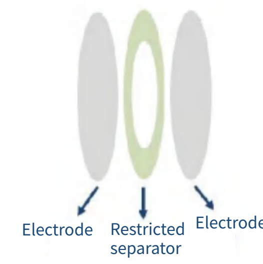
3.Synchronous testing across four channels.



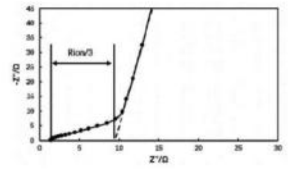
◆ Testing Principle:

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.

Symmetric cell



Computing method of MacMullin number



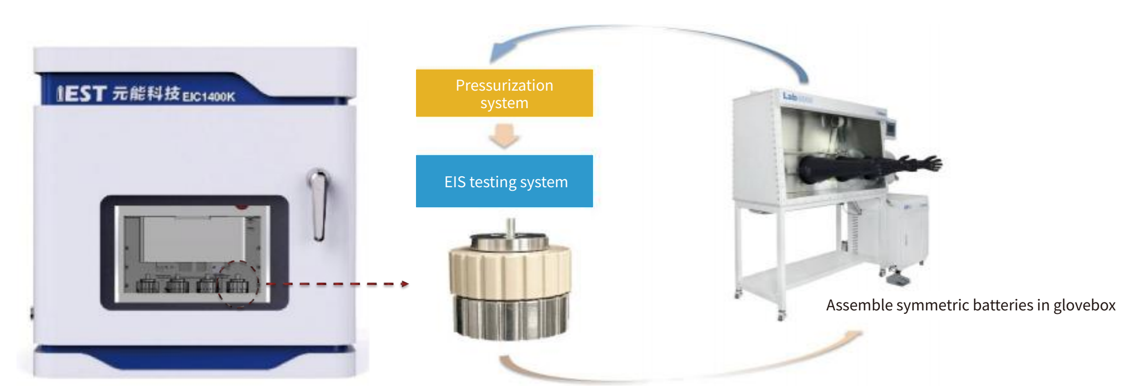
(Test value) (Known value)

$$\tau = (R_{ion} \cdot A \cdot \varepsilon \cdot \sigma)/2d$$

(MacMullin number) $N_m = \frac{k_{int}}{k} = \frac{\tau}{\epsilon}$ (Tortuosity) (Porosity)

τ :Tortuosity
Rion:Ionic resistance
A :Electrode area
ε :Electrode porosity
σ :Electrolyte conductivity
d :Electrode thickness

C Creative Solution Two

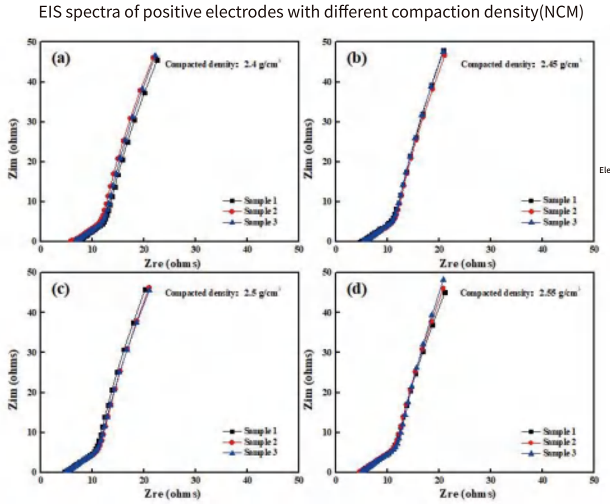


Multi-channel testing | Variable pressure testing | Fast EIS testing | Data fitting and analysis

D Application case

(1) Different compaction density of positive electrodes

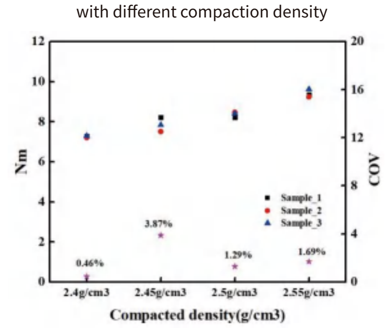
EIS spectra of positive electrodes with different compaction density(NCM)



$Nm = (R_{ion} \cdot A \cdot \sigma)/2d$

(Nm: MacMullin number R_{ion}: Ionic Resistance A: Electrode Area σ: Electrolyte Conductivity; d: Electrode Thickness)

MacMullin number of positive electrodes with different compaction density



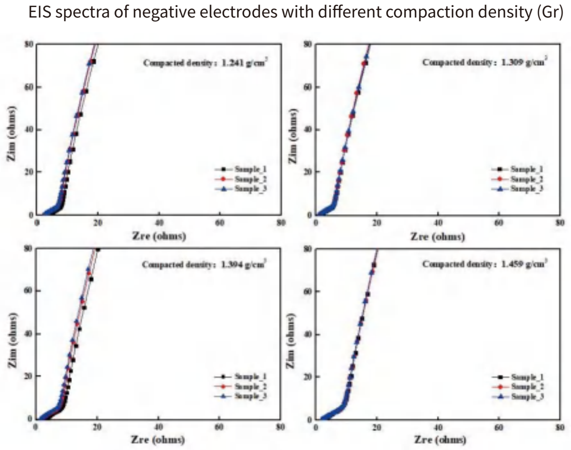
Summary:

① The consistency of EIS testing for symmetric battery of electrodes is generally good.

② 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

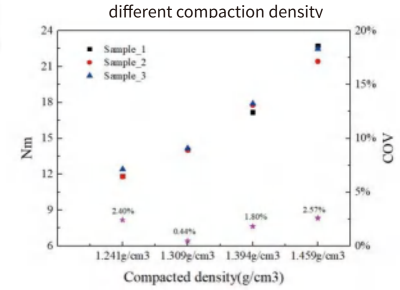
EIS spectra of negative electrodes with different compaction density (Gr)



$Nm = (R_{ion} \cdot A \cdot \sigma)/2d$

(Nm: MacMullin number R_{ion}: Ionic Resistance A: Electrode Area σ: Electrolyte Conductivity; d: Electrode Thickness)

MacMullin number of negative electrodes with different compaction density



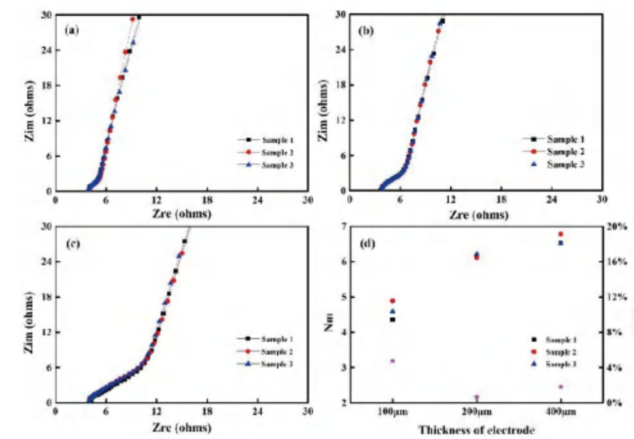
Summary:

① The consistency of EIS testing for symmetric battery of electrodes is generally good.

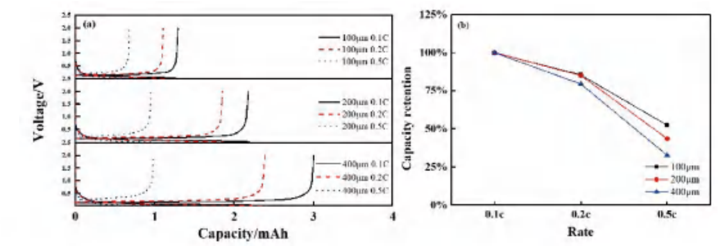
② Within a certain range of compaction density, as the compaction increases, the ion resistance/MacMullin number also increases.

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

Tortuosity testing of negative electrodes with different thicknesses

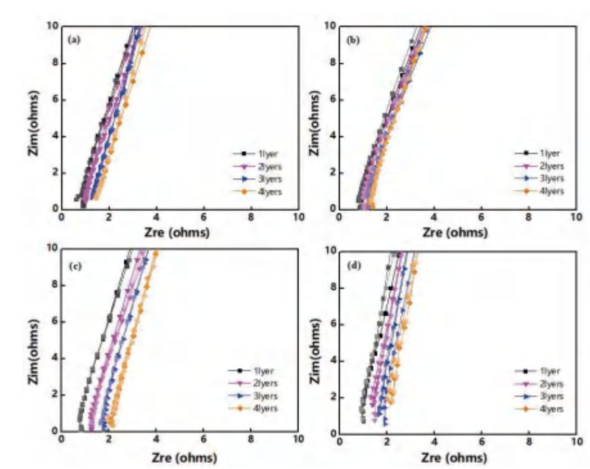


Rate performance testing

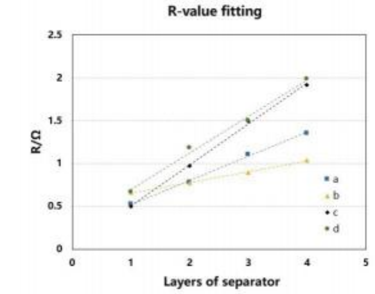


Summary: As the thickness of the electrode increases, its tortuosity also increases. However, the rate performance of the battery decreases with increasing thickness. This indicates that the rate performance of the battery decreases with increasing tortuosity. There is a certain correlation between electrode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

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



R-value fitting



Separator	The fitting formula	R^2
a	y = 0.2804x + 0.2414	0.9969
b	y = 0.1234x + 0.5306	0.9976
c	y = 0.477x + 0.0273	0.9986
d	y = 0.4266x + 0.2661	0.9921

$\sigma = d/(R*S)$

σ: Ionic conductivity

d: Membrane thickness

R: Resistance of single-layer separator

Separator	σ/ S/cm
a	0.0018
b	0.0048
c	0.0019
d	0.0014

Summary :

1、Test the EIS of 1-4 layers of separators to obtain R1, R2, R3, R4.

2、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 ⩾0.99.

3、Calculate the separator ionic conductivity according to the formula.

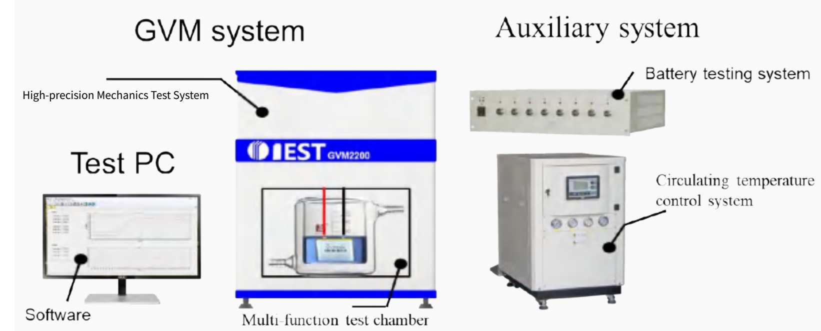
In-Situ Gassing Volume Analyzer

Scan QR code
for the details

A Differences between different models of GVM series

Model	GVM2100、GVM2200	GVM2150、GVM2250
Channel	single channel (single cell) two channels (two cells)	single channel (single cell) 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), ⩽20μL(RT25°C、30min~12h)	⩽30μL(RT25°C、⩽30min), ⩽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



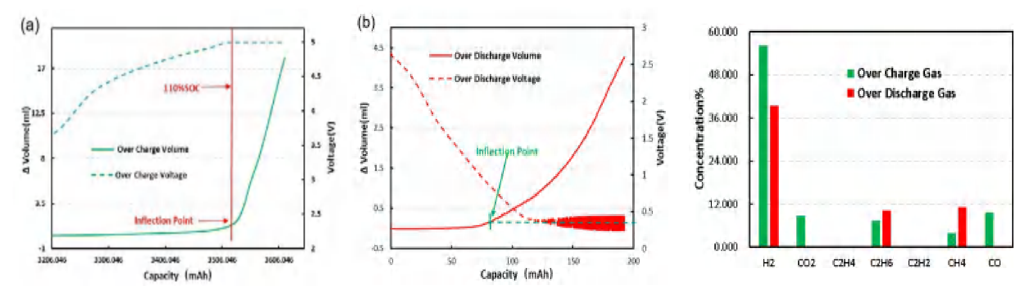
High-precision Mechanics Test System: long term& in-situ monitoring, and meet the accuracy requirements.

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

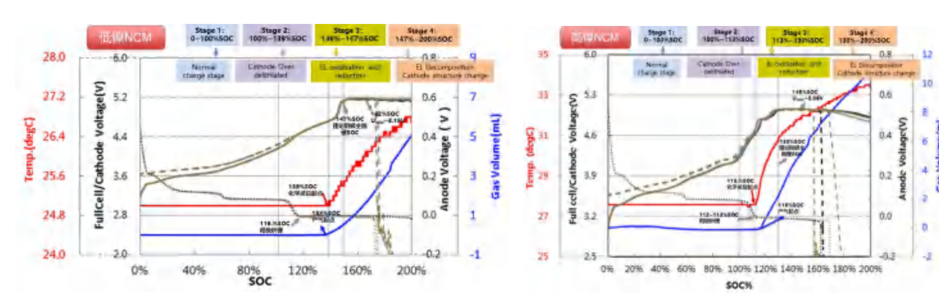
(1) Analysis of overcharge and overdischarge of LFP batteries



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_2 gas is also detected.

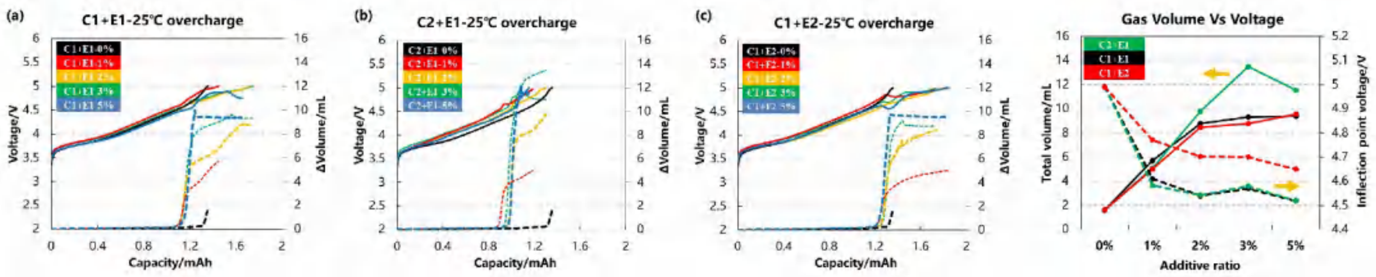
(2) Gassing Analysis for Different NCM Materials During Overcharging



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

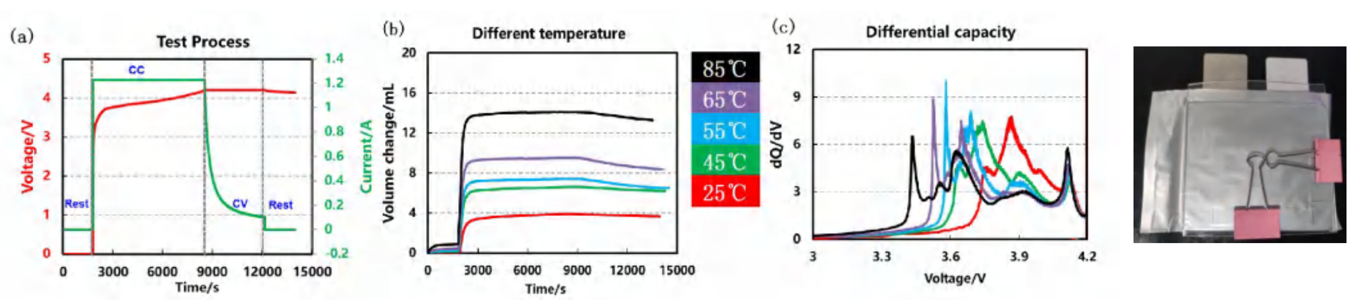


The radio of electrolyte additives	Gassing after overcharge to 5V(mL)			Voltage in gassing curve inflection point		
	C1+E1	C2+E1	C1+E2	C1+E1	C2+E1	C1+E2
0%	1.625	1.625	1.625	4.99	4.99	4.99
1%	5.708	5.068	5.005	4.61	4.583	4.77
2%	8.786	9.783	8.457	4.54	4.543	4.70
3%	9.335	13.479	8.785	4.57	4.58	4.70
5%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

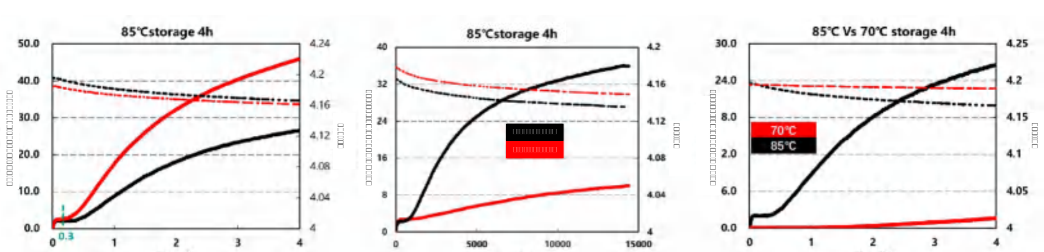
D Application Case - Analysis of Formation and Gas Production

(1) Formation at different temperatures



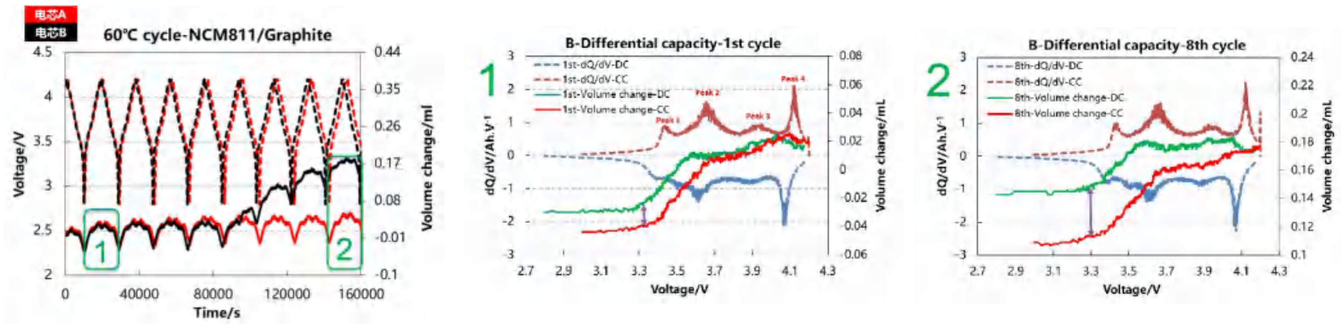
NCM/Graphite cells, 0.5C CC to 4.2V, theoretical capacity 2400mAh;
As the formation temperature increases, the corresponding gas production also gradually increases;
From the differential capacity curve, the increase of the formation temperature will reduce the polarization of each phase transition, 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.

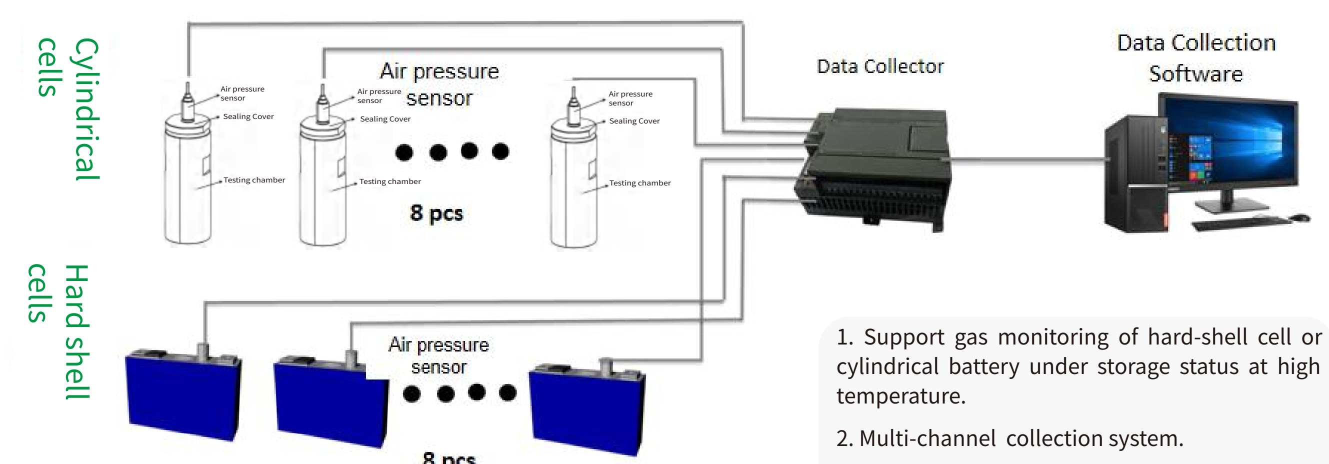
(3) Cyclic gas production analysis - comparison of different ternary materials



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.

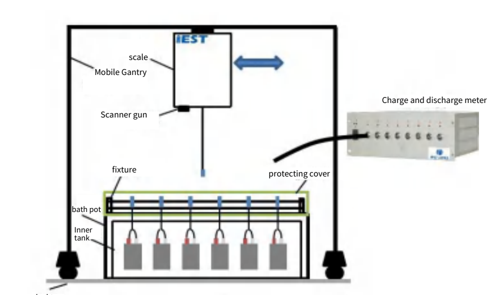
E In-Situ Gas Production Test System for Hard-Shell Cell



1. Support gas monitoring of hard-shell cell or cylindrical battery under storage status at high temperature.
2. Multi-channel collection system.
3. Reusable air pressure sensors.

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

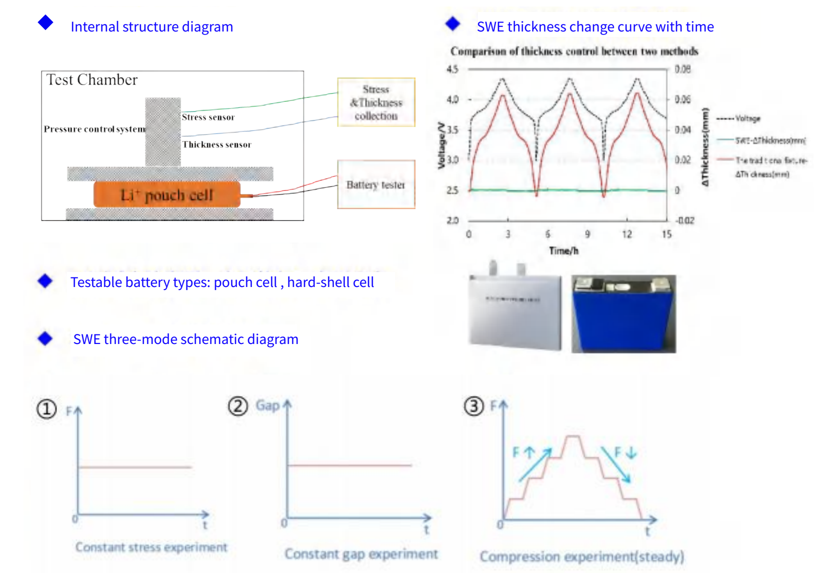
Model	SWE150P/T	SWE1400L	SWE2110、SWE2510	SWE2100、SWE2500
Pressing method	Manual: manual pressurization to the required pressure	Automatic: automatically controlled by software		
Testable parameter	Cell expansion force&thickness Pressure detection range: 0~50KN (could be customizable)	Cell expansion force、Cell Initial Thickness、Cell temperature、Cell expansion thickness、Cell Stress-Strain Curve		
Function	◆Constant pressure or constant gap mode: 1. Can apply a force of 10~5000kg; 2. The largest measurable cell size: 400*300*100 3. Temperature control: optional -20°C~60°C ◆The software automatically collects testable parameters ◆Software compatible with charging and discharging data ◆Multiple units can be connected in parallel ◆It can be placed in a high and low temperature box, the temperature range is -30~100°C	①Number of channels:4 ②Constant pressure mode (accuracy ±20μm) ③Pressure range:5T ④Provide high and low temperature environment:-20~60°C	①Number of channels:1 ②Constant pressure mode (accuracy ±1μm) ③Pressure range:1T (SWE2110)、5T (SWE2510)	①Number of channels:1 ②Constant pressure mode (accuracy ±1μm) ③Pressure range:1T (SWE2100)、5T (SWE2500) ④Provide high and low temperature environment:-20~80°C
		①Constant gap mode (accuracy ±0.3%F.S); ②Compression modulus mode; ③Software compatible with charging and discharging data; ④Automatic measurement software: automatic collection of expansion force, expansion thickness, cell temperature, free choice of mode, free setting of experimental parameters; ⑤Multiple units can be connected in parallel to realize synchronous testing ;		
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.

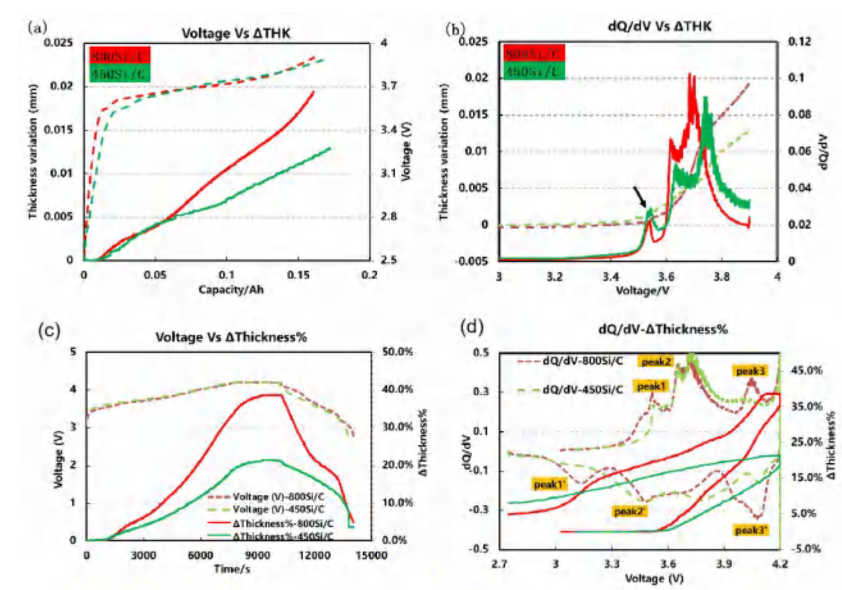
Multi-function test modes: the constant pressure and constant gap test modes can be realized for the cell, and the performance of the cell under different stress conditions can be evaluated.

High precision control: The traditional fixture will generate ~70um 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 ~1um 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



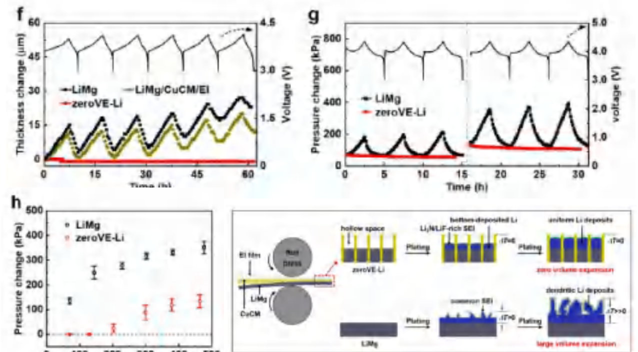
Information of battery	
Item	Parameter
Norminal capacity(Ah)	0.2
Cathode material	NCM811
Anode material	450Si/C-450mAh/g 800Si/C-800mAh/g

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 LixSi 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!



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D Application Case-Working Condition Evaluation

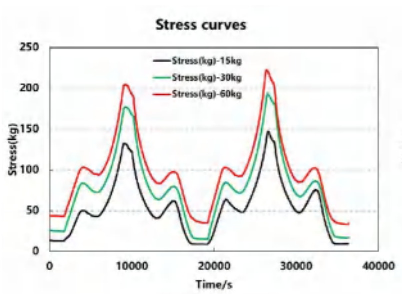
(1) Different Preload

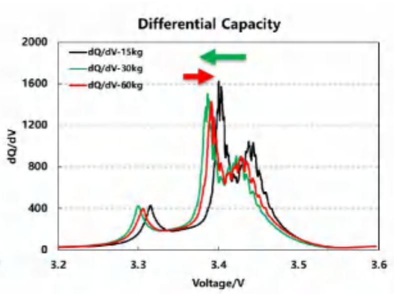
Pre-stress(kg)	Pre-stress(kPa)	Max Stress(kg)-1st cycle	Max Stress(kPa)-1st cycle
15	5	130	51
30	10	170	67
60	20	200	79

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

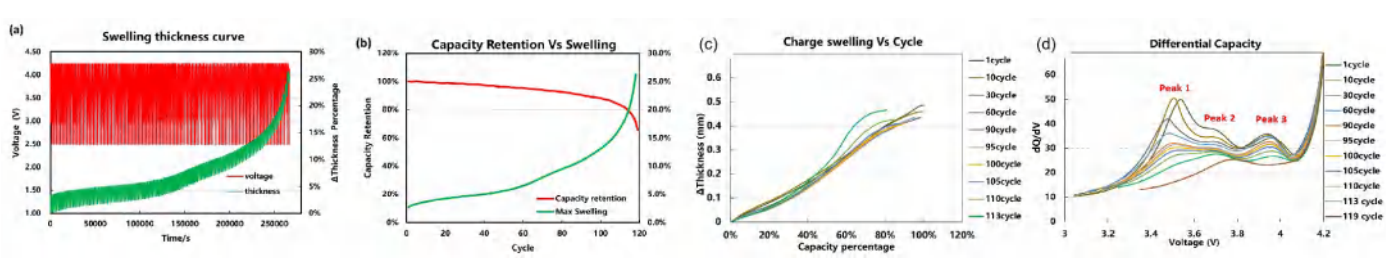
With the increase of preload, the initial gap of the cell gradually decreases, and the expansion force during the charging and discharging processes becomes larger. The relationship between the initial preload and the maximum expansion force can be further obtained to help the design of the battery module.

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;





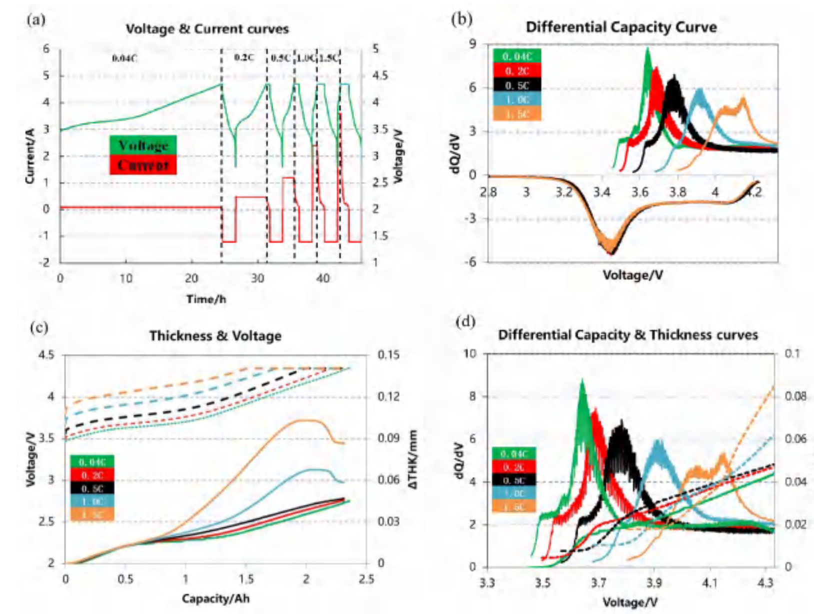
(2) Cycling Performance



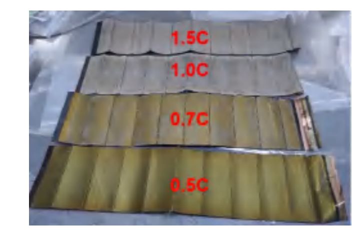
Test Conditions: 25°C 1C 3~4.2V;50Ah NCM811-Graphite
The relationship between capacity decay and thickness expansion during the long cycling of NCM cells was analyzed. Through the analysis of related expansion thickness and electrochemical data, it can be speculated that the reasons for the capacity decay of NCM cell include electrode mechanical damage, lithium plating and other side reactions.

E Non-destructive lithium plating analysis

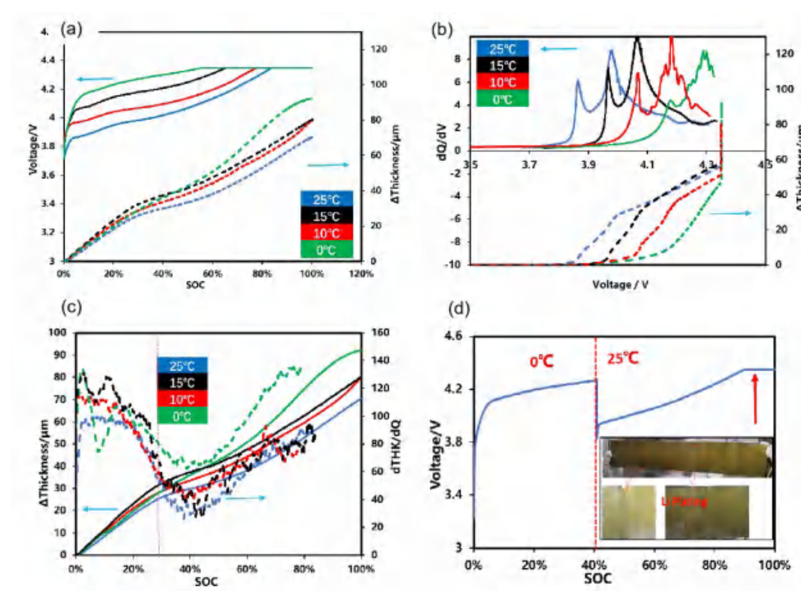
(1) Rate Window



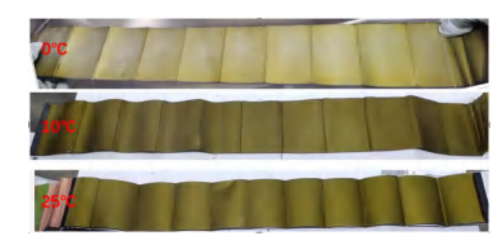
Test method: In situ detect the thickness curves of batteries with different charging rates.
Method of judgment: The thickness curve under a certain charging rate is compared with the thickness curve under a small charging rate which is without lithium plating, and the crotch position can be judged as the rate window of the lithium plating.



(2) Temperature Window

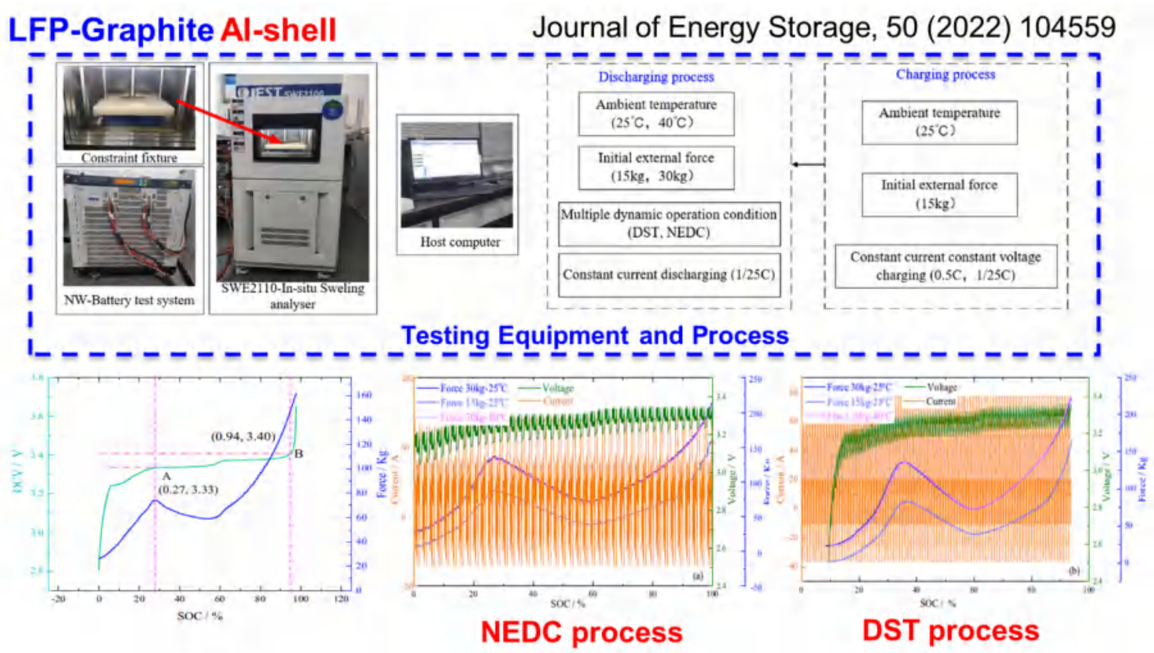


Test method: In situ detect the thickness curves of batteries with different temperatures.
Method of judgment: The position where the thickness curve at a certain temperature bifurcates compared with the thickness curve under high temperature which is without lithium plating is the temperature window of the lithium plating.



F Application Case-Hard-shell battery

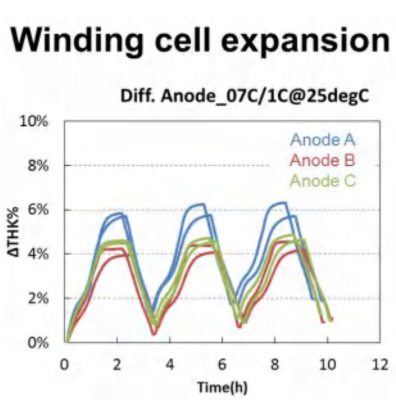
(1) SOC estimation based on the expansion force

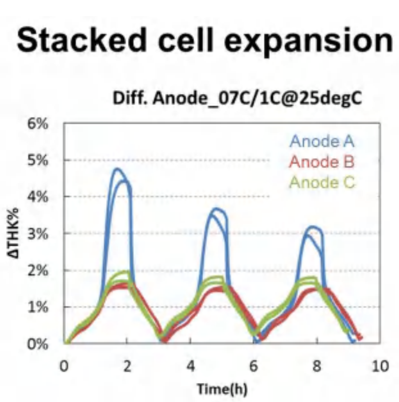


Based on LSSVM and AUKF algorithms, the method of using expansion force to estimate the SOC of LFP battery can achieve an estimation error of less than 1%, which is suitable for different working conditions of temperature, dynamic current and preload.

G Application Case-Cell structure

(1) M6S Vs SLS Structural comparison





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:

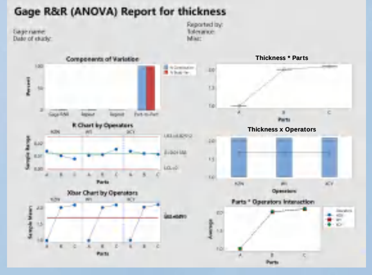
1. Return to zero: clear the system error and automatically return to zero;
2. Pressure: free choice of pressure within the range;
3. Thickness calibration block: check the thickness deviation of the measuring system;
4. Controlled by software, it can communicate with MES;
5. Ambient temperature and 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

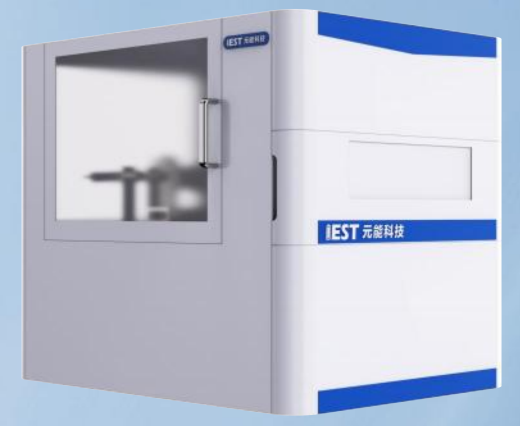
Source	StdDev (SD)	Study Var (6 × SD)	%Study Var (%SV)
Total Gage R&R	0.006255	0.03753	1.03
Repeatability	0.005223	0.03134	0.86
Reproducibility	0.003442	0.02065	0.57
Operators	0.003442	0.02065	0.57
Part-To-Part	0.605160	3.63096	99.99
Total Variation	0.605192	3.63115	100.00

Number of Distinct Categories = 136



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



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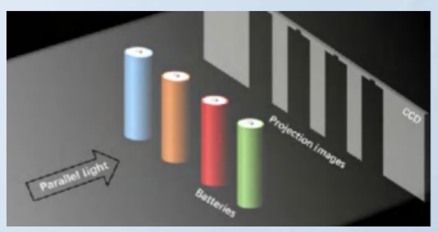
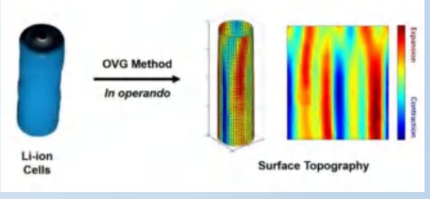
for the details

A Product Features





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

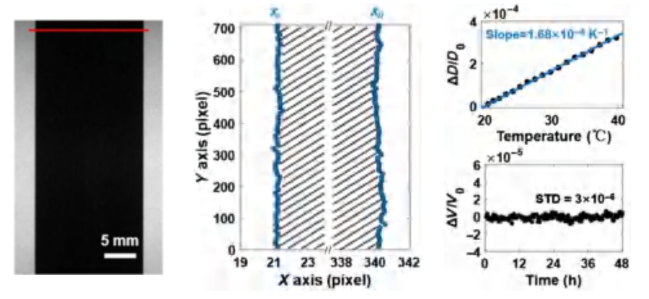
Real time reconstruction of battery surface morphology and calculation of volume deformation during charge and discharge processes. Combining voltage and current data to detect and predict battery health condition from a higher dimension.

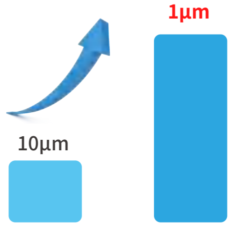
B Model Specifications Table

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

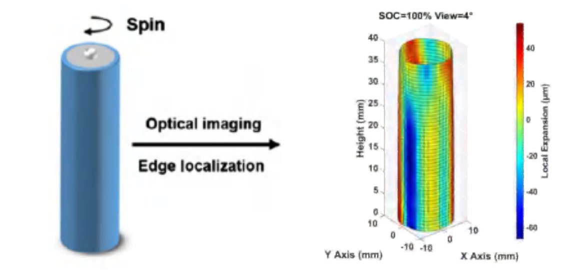
High-precision Detection Technology

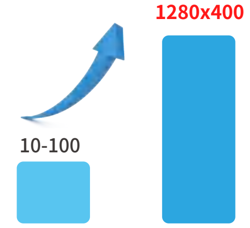




Measurement accuracy increased tenfold

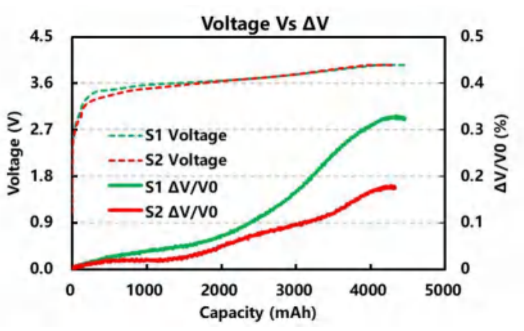
Rotational 3D Reconstruction Technology

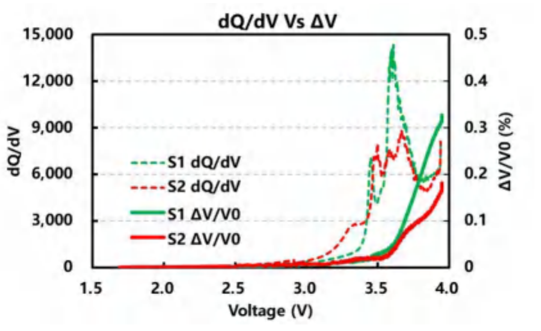




The number of sampling points increased by ten thousand times

D Application Case





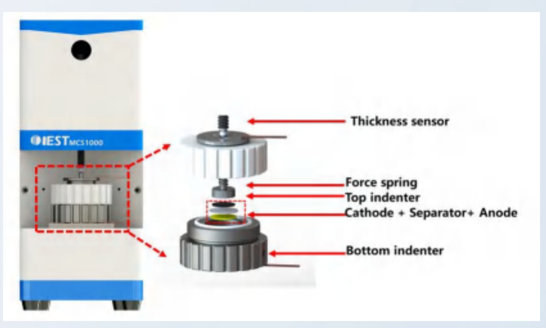
21700 Cell parameters：Sample 1-15%SiC；Sample 2-10%SiC

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.

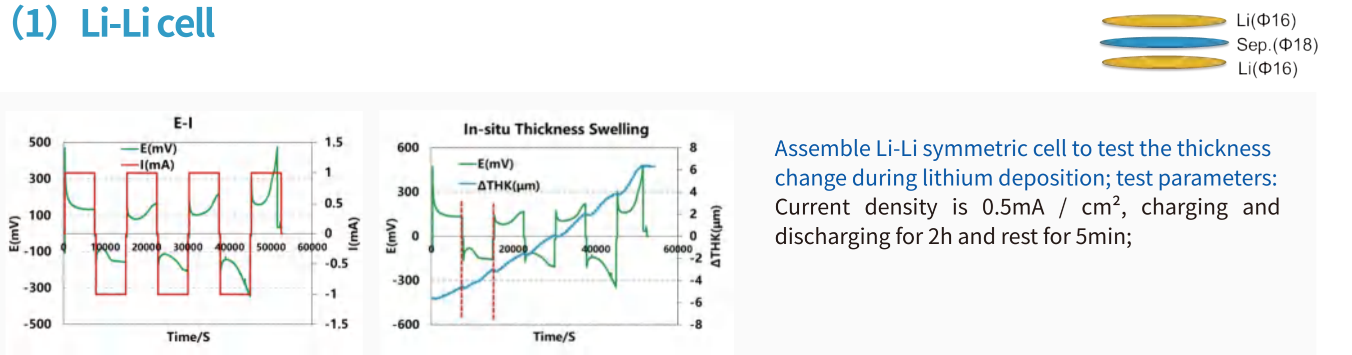
Applications:
Li-Li symmetrical cell
LCO/NCM/LFP-Li half-cell
NCM-Graphite full coin cell
NCM-Si/C full coin cell
All-solid-state battery

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

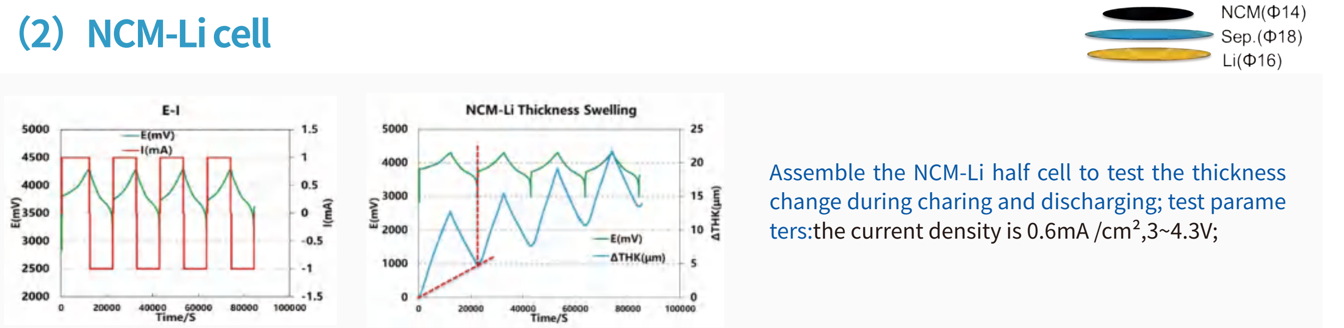
(1) Li-Li cell



Assemble Li-Li symmetric cell to test the thickness change during lithium deposition; test parameters: Current density is 0.5mA / cm^2, 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 mm3/mAh.

(2) NCM-Li cell

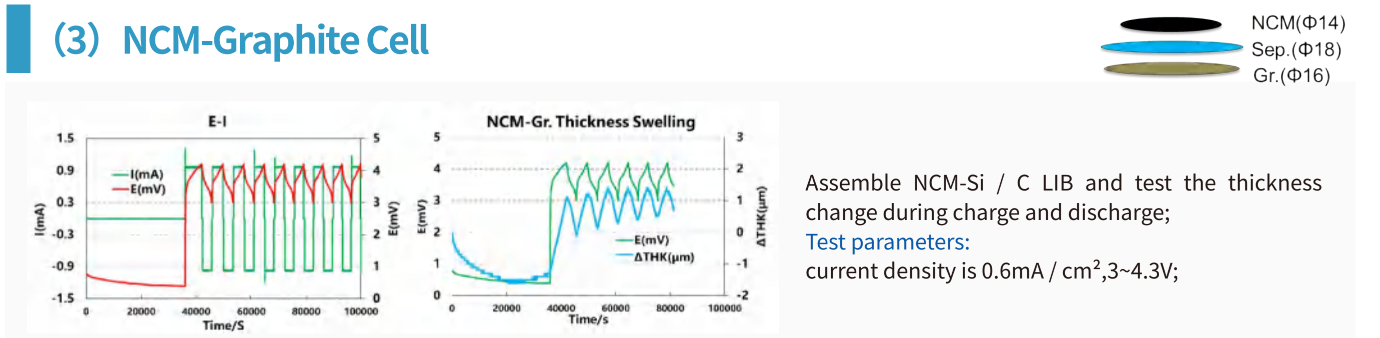


Assemble the NCM-Li half cell to test the thickness change during charing and discharging; test parame ters:the current density is 0.6mA /cm^2,3~4.3V;

During the charging process, the thickness expansion is about 4 μm/mAh, and the volume expansion is about (0.6 mm^3/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^3/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

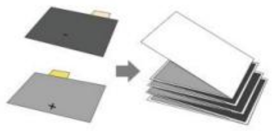


Assemble NCM-Si / C LIB and test the thickness change during charge and discharge;
Test parameters:
current density is 0.6mA / cm^2,3~4.3V;

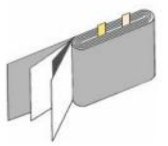
Ignore the expansion of NCM positive electrode, and the total expansion thickness measured from the model coin cell mainly comes from the expansion of the SiC negative electrode during the expansion experiment. By further deducting the thickness of the copper current collector, the thickness expansion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

Quickly evaluate the expansion properties of the material



The expansion behavior of electrode



In situ characterization of cell expansion

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

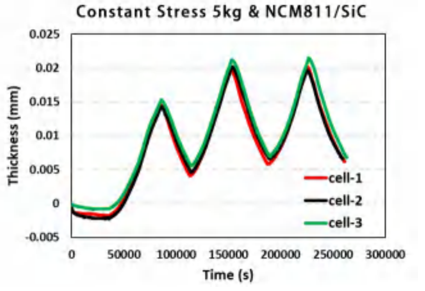
B Differences between different models of RSS series

Model	RSS1100	RSS1200	RSS1300	RSS1400
Number of channels	4		4	
Pressure regulation mode	with weight		with servo motor	
Pressure range	0.5kg/1kg/5kg (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)			

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) In-Situ expansion test of model coin cell



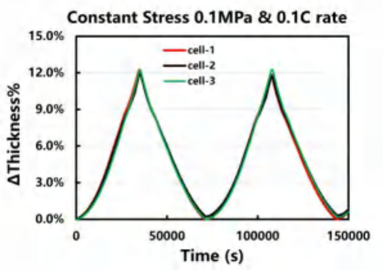
No.	charge Q/mAh	Thickness /mm
cell-1	3.13	0.0157
cell-2	3.07	0.0155
cell-3	3.11	0.0155
mean	3.10	0.0156
sigma	0.025	9.43E-05
cov	0.8%	0.6%

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 liminated cells

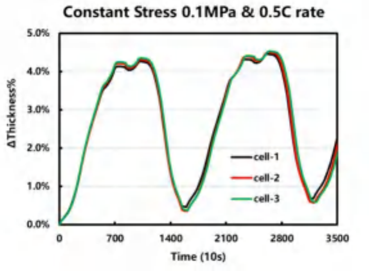


No.	charge Q/mAh	charge swelling/%
cell-1	371.2	12.5%
cell-2	371.6	12.1%
cell-3	374.1	12.2%
mean	372.30	12.3%
sigma	1.283	0.002
cov	0.3%	1.4%

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

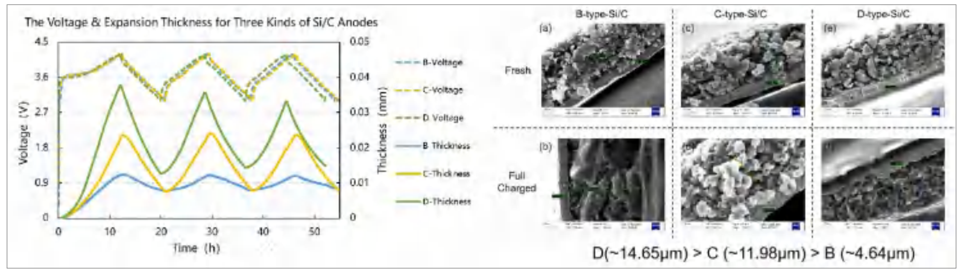


No.	charge Q/mAh	charge swelling/%
cell-1	4416.7	4.1%
cell-2	4445.4	4.2%
cell-3	4439.3	4.3%
mean	4433.8	4.2%
sigma	12.345	0.001
cov	0.3%	1.9%

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.

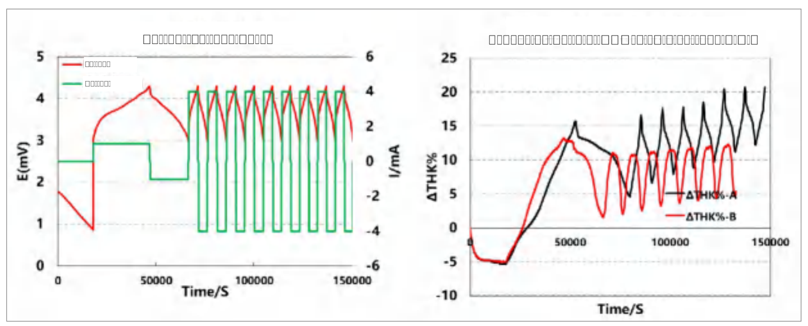
(4) Expansion of Si/C anodes with different modifications



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



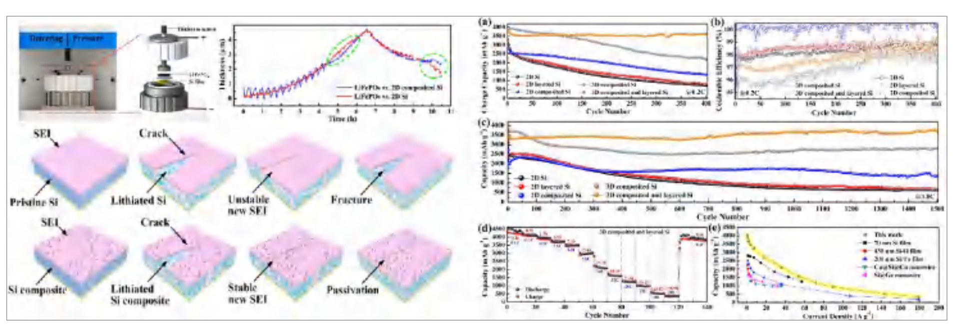
Assemble the NCM-Si/C coin cells, and test the thickness change during charging and discharging;
Test parameters: current density is 0.6mA/cm², 3~4.3V;

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

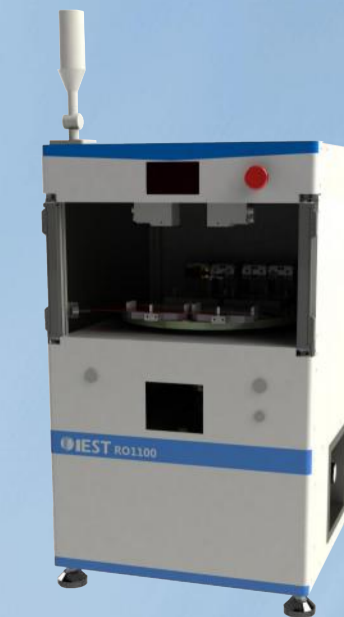
J. Lin et.al. Angew. Chem. Int. Ed. 2023, 62, e202216557



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

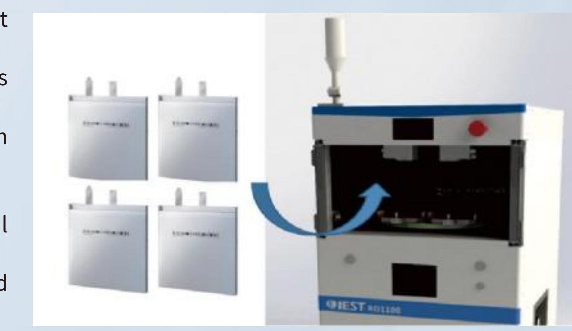


Scan QR code for the details

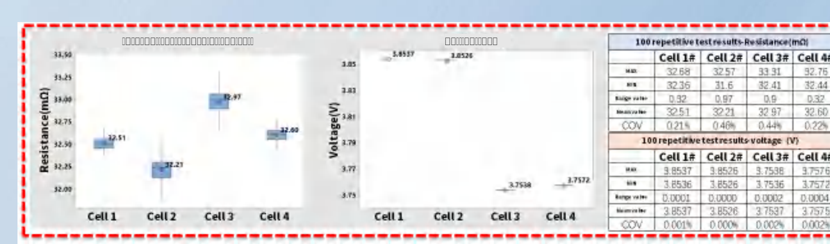
A Creative Solutions

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;

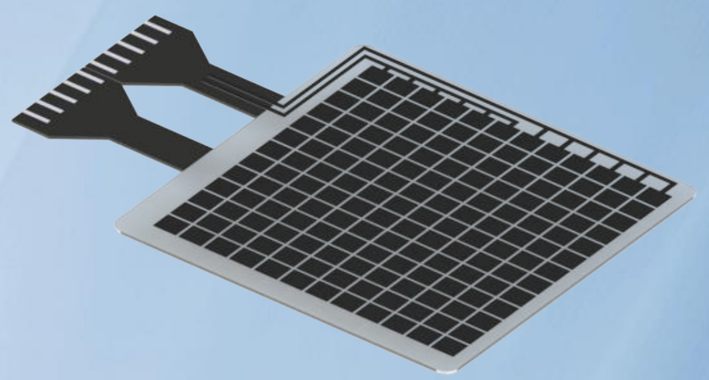


B Test Result



Item	Parameter
Resistance test range	0.1μΩ~3.1kΩ
Resistance test accuracy	±0.5%F.S
Voltage test range	0V~60V
Voltage test accuracy	±0.03%F.S
Test efficiency	≥15 个/min

Battery Pressure Distribution Measurement System

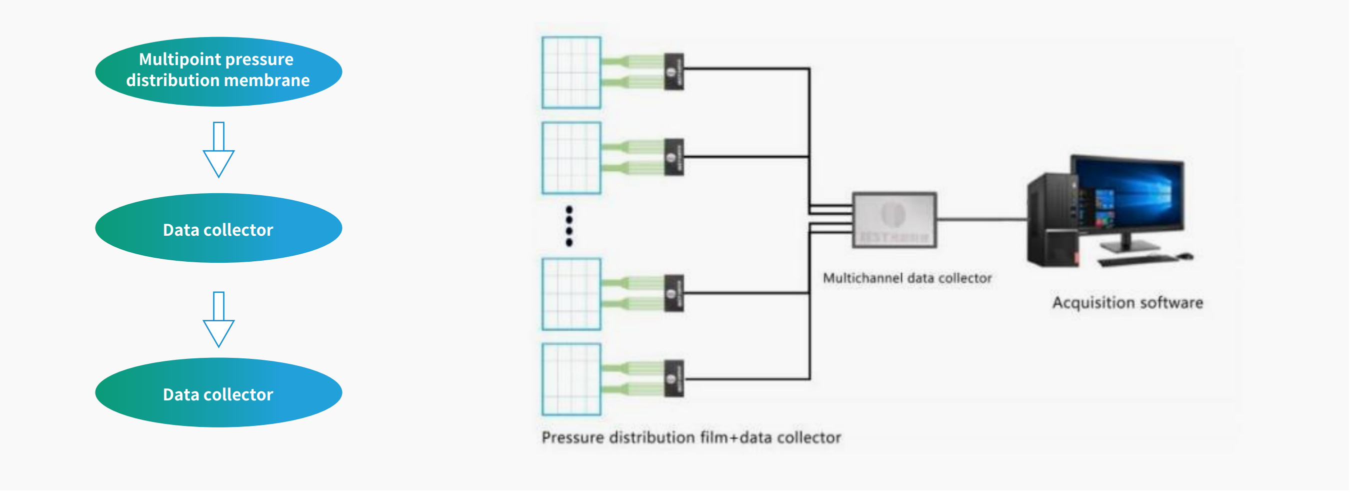


Scan QR code for the details

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 (Can be customized according to customer needs)
Data collector	1 (Sampling frequency<10Hz), size about 20*80*120mm(Height * width * length)
Software	1 set
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.	

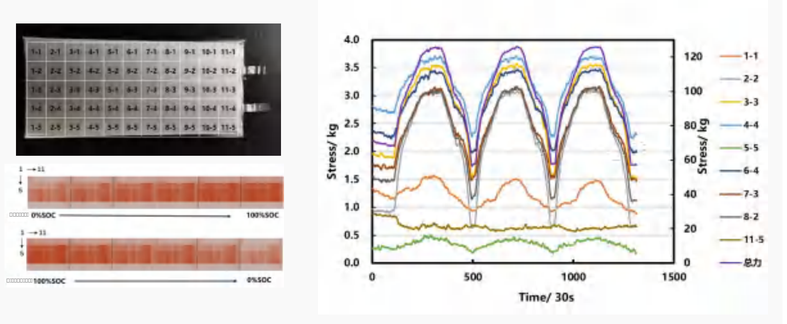
B Can support multi-channel integration



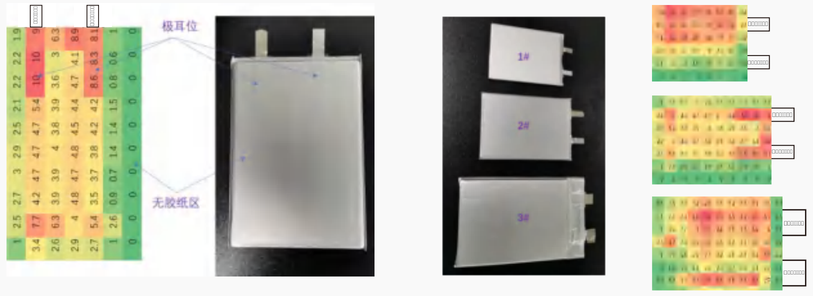
C Application Case

(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

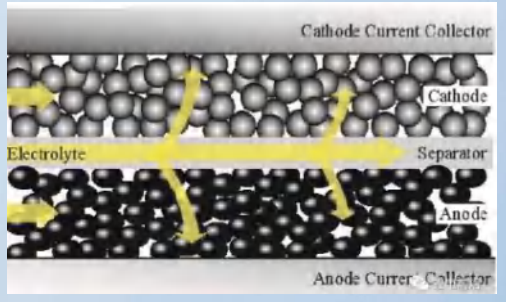
Electrolyte weight immersion system

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
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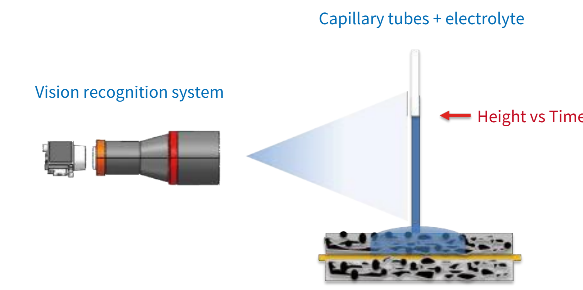
The Lucas-Washburn infiltration model is commonly used to describe the dynamic of liquid absorption in electrode pores, as represented by the equation below. Here, (h) denotes the liquid absorption height, (t) stands for absorption time, (c) represents the shape factor for different pore capillaries, (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.

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

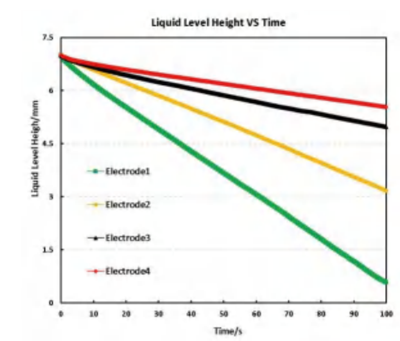
C Electrode electrolyte capillary wetting system

(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/cm³) <2 (1.5 g/cm³) <3 (1.6 g/cm³) <4 (1.65 g/cm³)

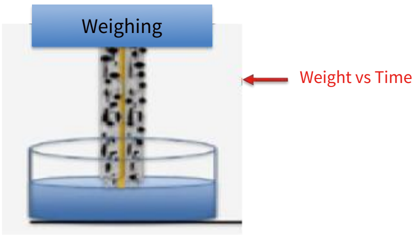
(3) Model and Parameters

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

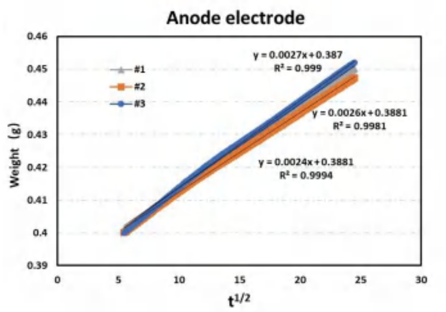
(1) sheets of lithium-ion batteries

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.



Testing Principle

(2) Application Case



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

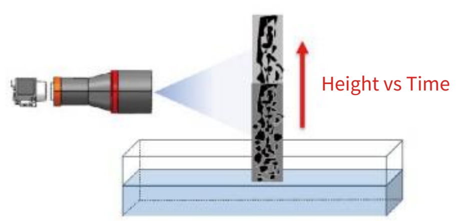
(3) Model and Parameters

ETS1100	
Balance capacity	0~220g
Balance precision	±0.1mg
Electrode size	65*70mm

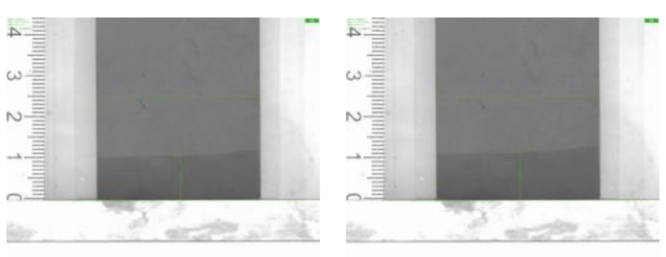
E Electrode Electrolyte Height Immersion System

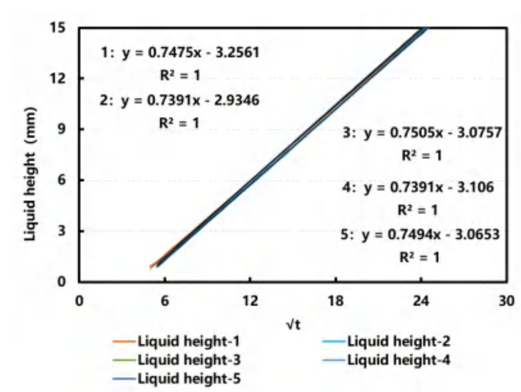
(1) Key Features

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.



Testing Principle





(2) Model and Parameters

CHT 1000	
Testing time	15min
Pixel precision	100µm
Electrode size	240*40mm

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

Customers:

CATL, BYD, ENVISION, Albemarle, ACC, Vianode, CABOT, Sila, EcoPro BM, Factorial, Mitra Chem, wisk, CUBERG, AM Batteries, OneD Battery Sciences, SINTE, 容百科技, AMIONX, CELLFORCE, AMITA, TOYOCOLOR