

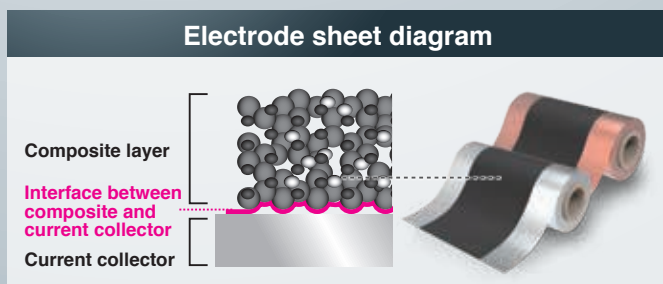


## Quantifying composite layer resistance and interface resistance in Li-ion battery electrode sheets

### Accelerating the evolution of LIBs

The RM2610 isolates and quantifies composite layer resistance and interface resistance\* in positive- and negative-electrode sheets used in lithium-ion batteries. Those values are helping LIBs to evolve and improve.

\*Contact resistance between the collector and composite layer

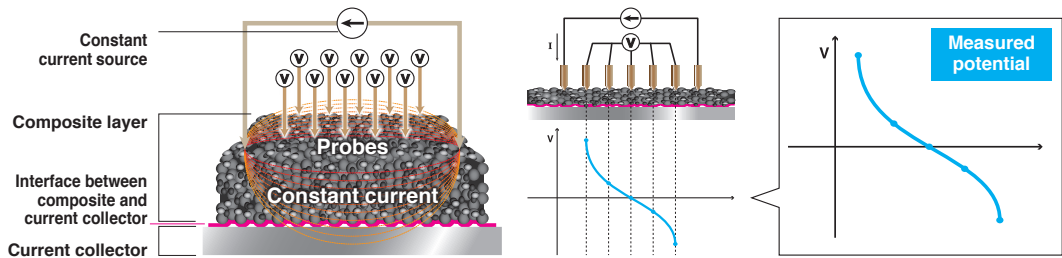


# Isolating and calculating composite layer resistivity and interface resistance using inverse problem analysis

## STEP 1

### Acquire the observed potential

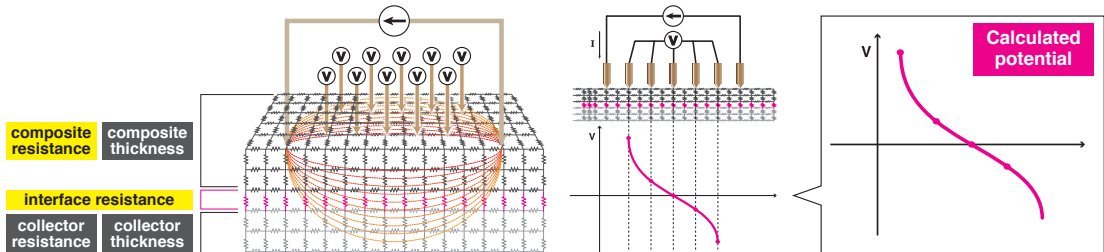
The RM2610 applies a constant current to the electrode sheet and measures the potential distribution occurring on the surface at multiple points.



## STEP 2

### Perform modeling and obtain the calculated potential

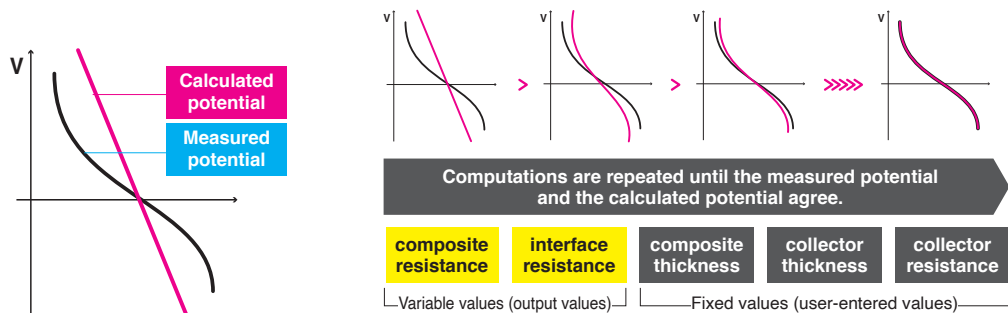
Next, the RM2610 models the electrode sheet and computes the potential occurring on its surface.



## STEP 3

### Repeatedly compute the calculated potential

Using composite resistance and interface resistance as variables, the RM2610 repeatedly computes the calculated potential until it agrees with the observed potential. Once the observed potential and calculated potential agree, the resulting variables are output.



The calculated potential is computed while varying the variables.

# LIBs are expected to evolve and improve

Accelerating development  
by quantifying the invisible quantity of resistance

## Example measurements

**Able to check the resistance difference in the different composite sheet**  
**Verify the uniformity of an electrode sheet**

| Sample: Positive electrode |   |
|----------------------------|---|
| Type                       | Positive electrode (lithium cobalt oxide)                       |
| Substrate                  | Aluminum foil (15 μm) with a volume resistivity of 2.7E-06 Ω cm |
| Active material            | LiCoO <sub>2</sub>  |
| Weight                     | 110.2 g / m <sup>2</sup>  |
| Overall thickness          | 92.1 μm   |
| Density                    | 2.95 g / cm <sup>3</sup>  |

Measurement results: Measuring 6 locations on electrode sheet

| Measurement location | Composite resistivity [Ω cm] | Interface resistance [Ω cm <sup>2</sup> ] |
|----------------------|------------------------------|---|
| A                    | 4.926E+00                    | 1.583E+00                                 |
| B                    | 4.894E+00                    | 1.824E+00                                 |
| C                    | 5.182E+00                    | 1.647E+00                                 |
| D                    | 4.938E+00                    | 1.390E+00                                 |
| E                    | 4.750E+00                    | 1.433E+00                                 |
| F                    | 5.312E+00                    | 1.147E+00                                 |

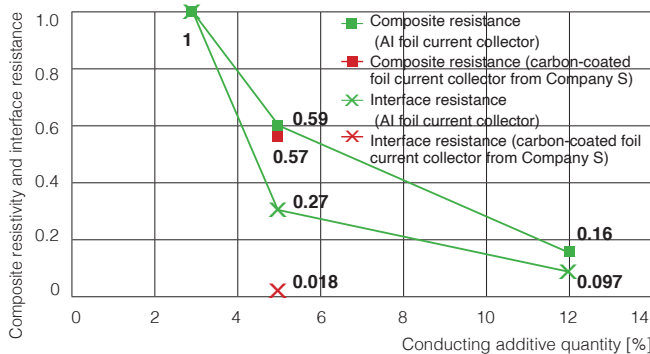
| Sample: Positive electrode |   |
|----------------------------|---|
| Type                       | Positive electrode (NMC 1:1:1)                                  |
| Substrate                  | Aluminum foil (15 μm) with a volume resistivity of 2.7E-06 Ω cm |
| Active material            | NMC 1:1:1   |
| Weight                     | 102.1 g / m <sup>2</sup>  |
| Overall thickness          | 54.8 μm   |
| Density                    | 2.75 g / cm <sup>3</sup>  |

Measurement results: Measuring 6 locations on electrode sheet

| Measurement location | Composite resistivity [Ω cm] | Interface resistance [Ω cm <sup>2</sup> ] |
|----------------------|------------------------------|---|
| A                    | 1.291E+01                    | 1.357E+01                                 |
| B                    | 1.222E+01                    | 1.964E+01                                 |
| C                    | 1.274E+01                    | 2.554E+01                                 |
| D                    | 1.269E+01                    | 1.180E+01                                 |
| E                    | 1.361E+01                    | 1.980E+01                                 |
| F                    | 1.315E+01                    | 2.066E+01                                 |

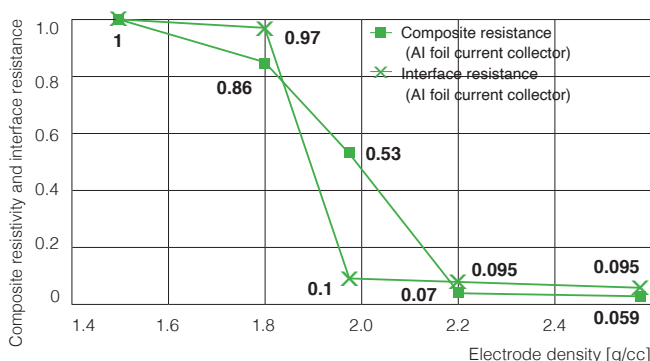
## Example uses

**Visualizing variations in composite layer resistance and interface resistance caused by differences in materials, composition, and manufacturing conditions**



**Ascertain the appropriate conducting additive quantity in order to lower interface resistance. Gauge the effect of carbon-coated foil on interface resistance.**

Referring to the graph, you can see how changing the conducting additive quantity changes composite resistivity and interface resistance. You can also see how interface resistance changes depending on whether carbon-coated film is present. Finally, you can see that composite resistivity and interface resistance are being isolated and calculated separately based on the fact that the composite resistivity remains the same regardless of whether or not carbon-coated film is present.



**Analyze the effects of electrode density on interface resistance.**

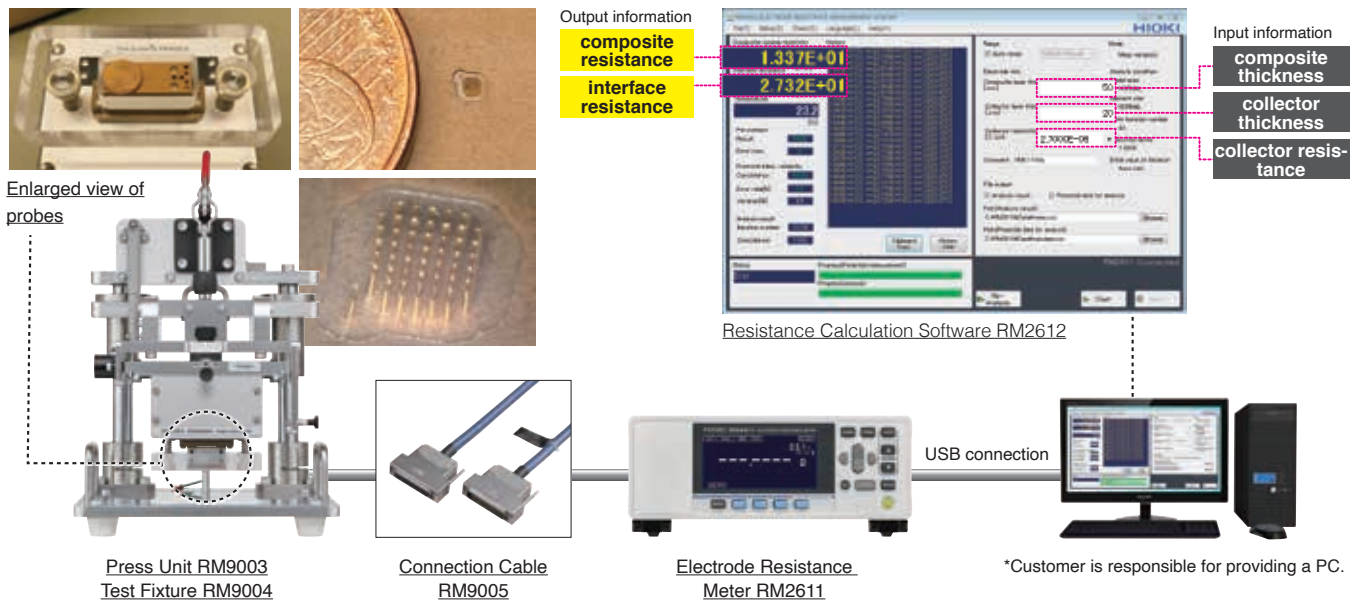
This graph illustrates the results of measuring an electrode while changing the press voltage to vary the electrode density. Although both the volume resistivity of the composite layer and interface resistance decrease as the press voltage and electrode density rise, the interface resistance drops precipitously after a certain point. The roughly constant value after that decline is useful in determining the optimal value.

\*The top and bottom graphs indicate relative composite resistivity and interface resistance values, where a value of 1 indicates the composite resistivity and interface resistance at a conducting additive quantity of 3% or an electrode density of 1.5 g/cc, respectively.

**\*Please verify the usefulness of the calculated output values by measuring your own samples.**



# Electrode Resistance Measurement System RM2610: System components



|   |   |  |   |
|---|---|--|---|
| <h3>Pre-work inspection</h3> <p>You can verify the state of the probes using the probe check board.</p> | <h3>User interface</h3> <p>Move the cursor to a parameter to view guidance including a description and valid setting range.</p> | <h3>Locking mechanism designed for safety</h3> <p>Pull the lock lever toward you to allow the probes to be lowered. This design keeps the probes from being lowered inadvertently.</p> | <h3>Tilting mechanism for easy maintenance</h3> <p>Rotate the press unit so that it faces towards the front, making it easy to clean the tips of the probes with air.</p> |
|---|---|--|---|

## Specifications

|                                       |  |
|---------------------------------------|--|
| Measurement target                    | Positive and negative electrode sheets for rechargeable lithium-ion batteries  |
| Measurement parameters                | Composite resistivity [ $\Omega\text{cm}$ ]<br>Interface resistance (contact resistance) between the composite layer and current collector [ $\Omega\text{cm}^2$ ]   |
| Computation method                    | Inverse problem analysis of potential distribution using the finite volume method  |
| Information necessary for computation | <ul style="list-style-type: none"> <li>Composite layer thickness [<math>\mu\text{m}</math>] (for 1 side)</li> <li>Current collector thickness [<math>\mu\text{m}</math>]</li> <li>Current collector volume resistivity [<math>\Omega\text{cm}</math>]</li> </ul> |

\*The RM2611 Electrode Resistance Meter requires regular calibration. For more information about calibration, please contact your HIOKI distributor

|                                  |  |
|----------------------------------|--|
| Measurement time                 | <ul style="list-style-type: none"> <li>Contact check + potential measurement: Approx. 30 s</li> <li>Calculation: Approx. 35 s (On a PC with Intel core i5-7200U CPU)</li> <li>* The measurement time depends on the measurement target and the processing capacity of the PC.</li> </ul> |
| Measurement current              | 1 $\mu\text{A}$ (min.) to 10 mA (max.)   |
| Number of probes                 | 46   |
| Recommended PC specifications    | CPU: 4 or more threads<br>RAM: 8 GB or greater (4 GB required)<br>Operating system: Windows 7 (64-bit), 8 (64-bit), 10 (64-bit)  |
| Temperature measurement function | Measures temperature near the test fixture   |
| Accessories                      | Temperature Probe Z2001, USB cable, USB license key, probe check board, power cord, user manual  |

Note: Company names and product names appearing in this brochure are trademarks or registered trademarks of various companies.

**HIOKI**  
HIOKI E. E. CORPORATION

**HEADQUARTERS**  
81 Koizumi,  
Ueda, Nagano 386-1192 Japan  
<https://www.hioki.com/>



Scan for all regional contact information

DISTRIBUTED BY