

Application News

Strength Testing of Lithium-Ion Battery Materials Using a Continuous-Testing Micro-Compression Testing Machine

Mana Oshiro

User Benefits

- ◆ The tests are automated, which significantly reduces the time required of the operators.
- ◆ Up to 100 continuous tests can be performed.
- ◆ Particle size measurement is performed by software, which reduces differences in measurement between operators.

Introduction

Lithium-ion batteries have become an indispensable energy source in a wide range of fields, from everyday items like smartphones and laptops to electric vehicles and renewable energy storage systems. The batteries consist of a positive electrode, a negative electrode, an electrolyte, and a separator. Positive electrodes use transition metal oxides (e.g., lithium nickel manganese cobalt oxide [NMC]) or lithium iron phosphate (LFP) to transfer lithium, and negative electrodes generally use graphite and, recently, high-capacity materials, such as silicon. One of the issues with lithium-ion batteries is that the positive and negative electrodes are prone to cracking. This is caused by the high pressures during manufacturing, as well as during charging and discharging. This is also thought to affect their performance, such as the cycle properties. Therefore, research is being conducted on the relationship between mechanical properties and the electrochemical performance.^{1), 2)}

This Application News presents compression tests on various battery materials as examples of quantitative evaluations of their mechanical properties. The MCT series of micro-compression testing machines can perform compression testing of minute single particles. In addition, the MCT-AD model can automatically perform extraction of measurement particles, length measurements, and test operations. This results in significant time savings and enables evaluations with a larger number of measurements.

MCT-AD Micro Compression Testing Machine

Fig. 1 shows the MCT-AD and the measurement principle. The MCT compressed single particles placed on a lower compression plate using a flat indenter. Then, using data on diameters of the particles obtained in advance, a test force-displacement graph was created that measured various types of strength of the particles.

The MCT-AD automatically performs selection of the measurement particles, length measurements, and cleaning of the indenter, which in the past had to be performed manually by the operator after each measurement. This enables continuous testing up to 100 times while consolidating the operation time by the operator and reducing labor.

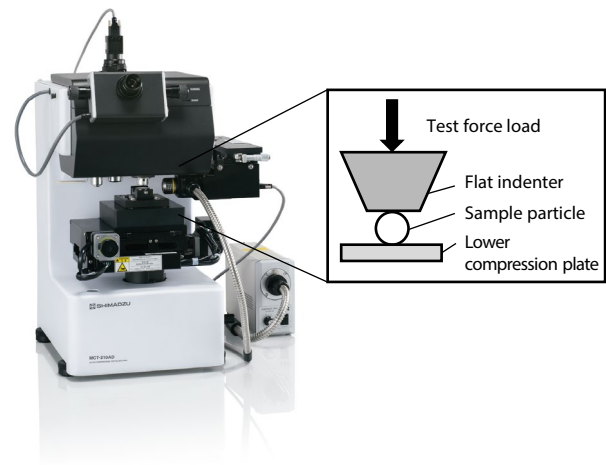


Fig. 1 MCT™-AD Measurement Principle

The flow of measurements using the MCT-AD is shown in Fig. 2. The samples were dispersed onto the lower compression plate. After setting the test conditions, the specified area was scanned while the electric XY slide stage was operating. The system automatically detected particles from a wide-area image created by combining all of the images obtained. Length measurements were automatically performed on each particle, and the specified number of particles suitable for the test were extracted. Then the compression testing and cleaning process was automatically repeated.

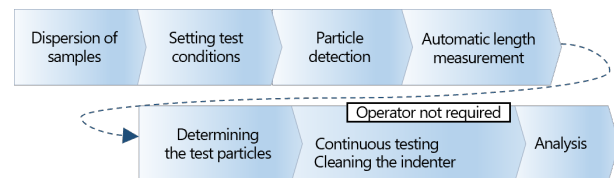


Fig. 2 Flow of Measurement Using the MCT-AD

Test Conditions

When conducting continuous testing, it is necessary to perform a single test beforehand to confirm and set appropriate test conditions. Afterward, the extraction criteria are set, such as the particle length measurement method, the particle size range, and the circularity, and particles suitable for the test are selected. Table 1 shows the test conditions for the positive electrode material, and Table 2 shows the test conditions for the negative electrode material. A crush strength coefficient of 2.8 (in accordance with JIS Z8844) was selected. Fig. 3 shows the measured particle images.

Table 1 Positive Electrode Material Test Conditions

Sample:	Positive electrode (NMC811 type)
Particle Diameter:	About 10 to 15 μm
Testing Machine:	MCT-211AD Micro Compression Testing Machine Flat Indenter $\Phi 50$, Side Observation Kit
Test Mode:	Compression test
Test Force:	50 mN
Loading Rate:	2.2 mN/sec
Measurement Method:	Particle area/diameter of circle with equivalent area
Circularity:	85 % or higher
Aspect Ratio:	0.88 % or higher

Table 2 Negative Electrode Material Test Conditions

Sample:	Negative electrode material (graphite type)
Particle Diameter:	About 10 to 15 μm
Testing Machine:	MCT-211AD Micro Compression Testing Machine Flat Indenter $\Phi 50$, Side Observation Kit Soft sample measurement mode*Next page, low test force option
Test Mode:	Compression test
Test Force:	8 mN
Loading Rate:	0.07 mN/sec
Measurement Method:	Maximum length/maximum diameter perpendicular length
Circularity:	70 % or higher
Aspect Ratio:	0.70 % or higher

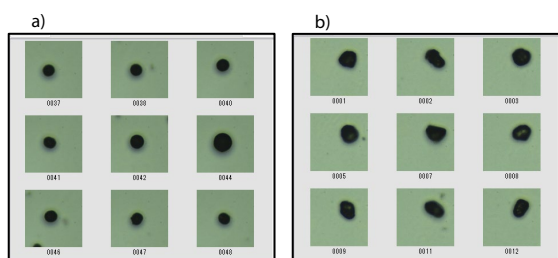


Fig. 3 Images of Particles Subjected to Length Measurement
a): Positive Electrode Material, b) Negative Electrode Material

■ Results of Positive Electrode Material Measurements

Continuous testing was performed on 100 samples. The positive electrode material used in these tests exhibited fracture behavior, so the fracture strength was evaluated. Using the analysis function, the fracture strength was evaluated based on 70 samples that were close to the median value. The results showed an average value of 125.3 MPa and a standard deviation of 15.1. Fig. 4 shows the test force - displacement graph, and Fig. 5 shows the strength - particle diameter graph.

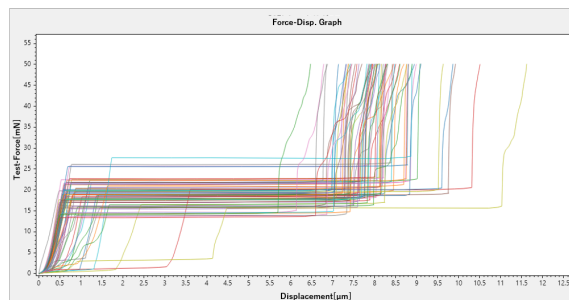


Fig. 4 Positive Electrode Material Test Force - Displacement Graph (N70)

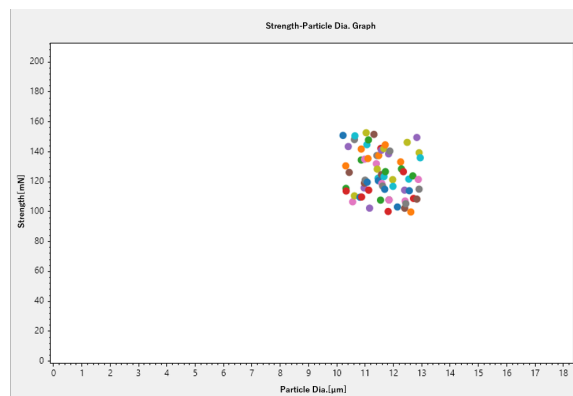


Fig. 5 Positive Electrode Material Strength - Particle Diameter Graph (N70)

Sample images from tests can also be saved and checked during analysis (Fig. 6). An optional side observation kit was used to observe the samples from the side during testing (Fig. 7). It enables particle compression to be observed in real time, and the data can be saved on video.

As a comparison, this test was also performed using a conventional machine. The testers had to spend more than five hours operating the machine. However, with the MCT-AD, they only had to perform condition-setting, which took about 20 minutes. After that, everything else was performed automatically. As a result, the operator's working time was reduced to less than 1/15 of the conventional time, so significant labor savings were achieved.

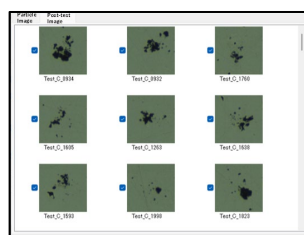


Fig. 6 Post-Test Images

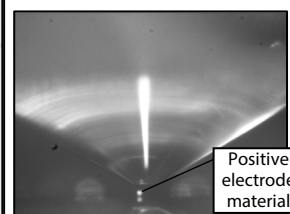


Fig. 7 Side Observation Kit

■ Results of Negative Electrode Material Measurements

Continuous testing was performed on 100 samples. The negative electrode material used in these tests rarely exhibited clear fracture behavior, so the deformation strength calculated from a test force at a 10 % deformation of the particle size was used for the evaluation. Also, because the sample was soft and surface recognition was difficult, a dedicated mode (soft sample measurement mode) was used for the measurement. Using the analysis function, the deformation strength was evaluated based on the data of 50 samples that were close to the median value. The results showed an average value of 1.8 MPa and a standard deviation of

0.5. Fig. 8 shows the test force-displacement graph and an enlarged view of the area around 10 % particle diameter deformation for calculating deformation strength.

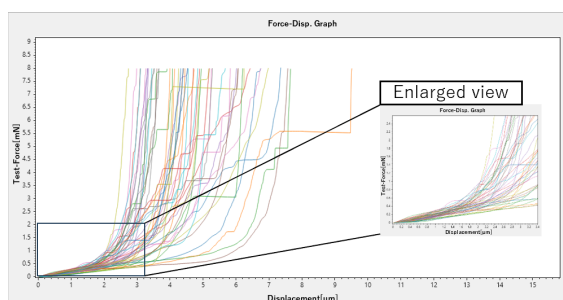


Fig. 8 Negative Electrode Material Test Force - Displacement Graph (N50)

■ Dispersion of Samples

Since the MCT series performs strength testing of single particles, only a single particle must be placed under the indenter. Therefore, samples are dispersed on the lower compression plate so that they do not overlap. In this case, the sample dispersion unit (a negative pressure method using a syringe) shown in Fig. 9 was used to easily disperse the sample onto the lower compression plate.

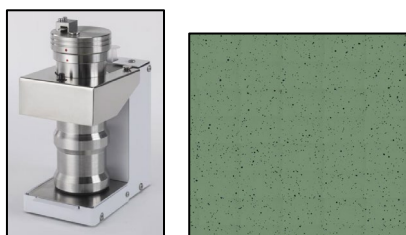


Fig. 9 Sample Dispersion Unit and Positive Electrode Material Dispersion Status (Wide-Area Image 2 x 2 mm)

■ Conclusion

This Application News presents a mechanical evaluation by the MCT-AD of materials used in the electrodes of lithium-ion batteries. Traditionally, this measurement process imposes a heavy workload on operators. But since the MCT-AD automatically performs extraction of measurement particles, length measurements, and test operations, there are significant labor savings, and the need for highly skilled operators is also eliminated. The MCT-AD can also handle compression testing of samples with minute particle shapes, not just battery materials, so it is useful not only for product development but also for quality control.

Acknowledgments

We wish to express our heartfelt thanks to KRI Inc. for kindly providing the positive electrode material samples used in this Application News.

References

- 1) Moon et al, "The correlation between particle hardness and cycle performance of layered cathode materials for lithium-ion batteries," *Journal of Power Sources*, 486 (2021) 229359.
- 2) Omirkhan et al, "Investigating the effect of lithiation on polycrystalline NMC811 Li-ion battery cathode cracking using in situ SEM micromechanical testing," *Energy Environ. Sci.*, 18 (2025) 9254

MCT is a trademark of Shimadzu Corporation or its affiliated companies in Japan and/or other countries.



Shimadzu Corporation

www.shimadzu.com/an/

For Research Use Only. Not for use in diagnostic procedures.

This publication may contain references to products that are not available in your country. Please contact us to check the availability of these products in your country.

The content of this publication shall not be reproduced, altered or sold for any commercial purpose without the written approval of Shimadzu. See <https://www.shimadzu.com/about/trademarks/index.html> for details.

Third party trademarks and trade names may be used in this publication to refer to either the entities or their products/services, whether or not they are used with trademark symbol "TM" or "®".

Shimadzu disclaims any proprietary interest in trademarks and trade names other than its own.

The information contained herein is provided to you "as is" without warranty of any kind including without limitation warranties as to its accuracy or completeness. Shimadzu does not assume any responsibility or liability for any damage, whether direct or indirect, relating to the use of this publication. This publication is based upon the information available to Shimadzu on or before the date of publication, and subject to change without notice.

01-01168-EN

First Edition: May 2026

➤ Please fill out the survey

Related Products

Some products may be updated to newer models.



Related Solutions

➤ Clean Energy

➤ Lithium-ion Battery

➤ Automotive

➤ Engineering
Materials

➤ Glass, Ceramics

➤ Price Inquiry

➤ Product Inquiry

➤ Technical Service /
Support Inquiry

➤ Other Inquiry