Report on Additional Pulverization of Fe–6.5 wt% Si Ribbon Fragments Using a Converge Mill

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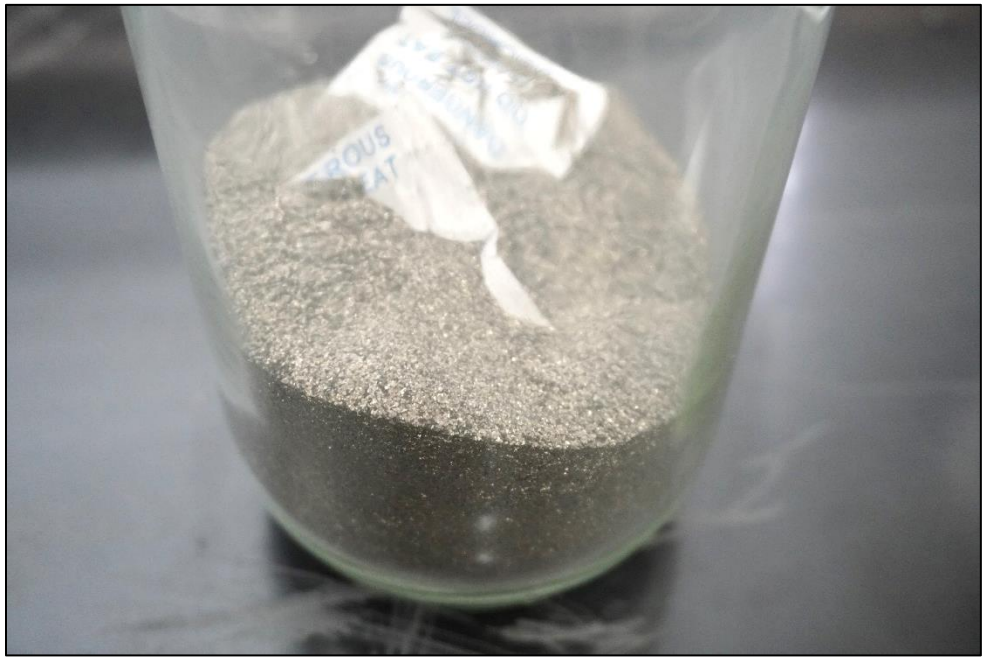
R&D Co., Ltd.
We try to innovate the rapid solidification processing

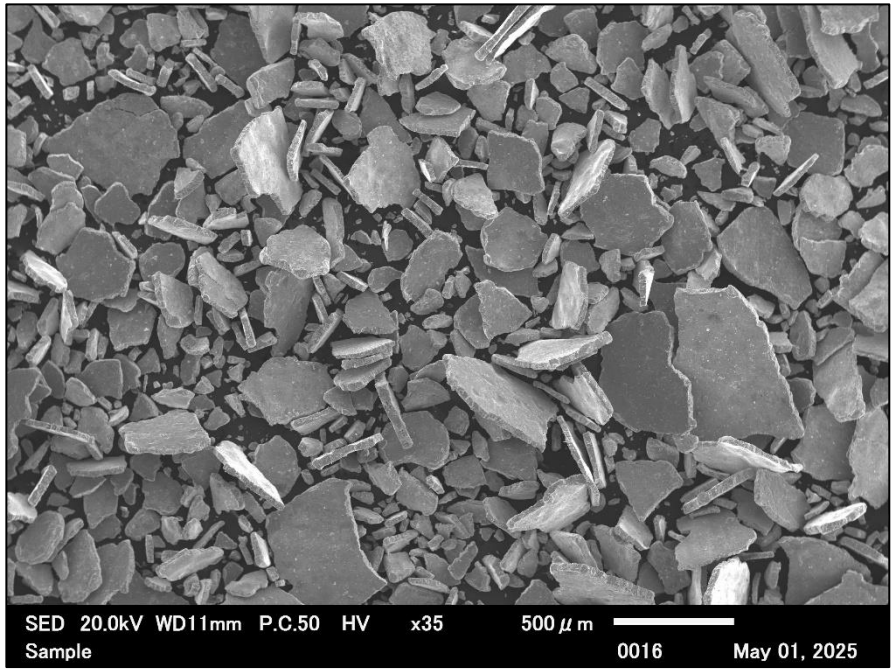
Overview of Additional Pulverization of Fe–6.5 wt% Si Ribbon Fragments Using a Converge Mill

In this study, ribbon scraps generated after slitting Fe–6.5 wt% Si ribbons produced by a rapid solidification process were subjected to primary pulverization, followed by additional pulverization using our Converge Mill, to evaluate the feasibility of producing powders with particle sizes of approximately 30 µm.

Primary-Pulverized Fe–6.5 wt% Si Ribbon Sample

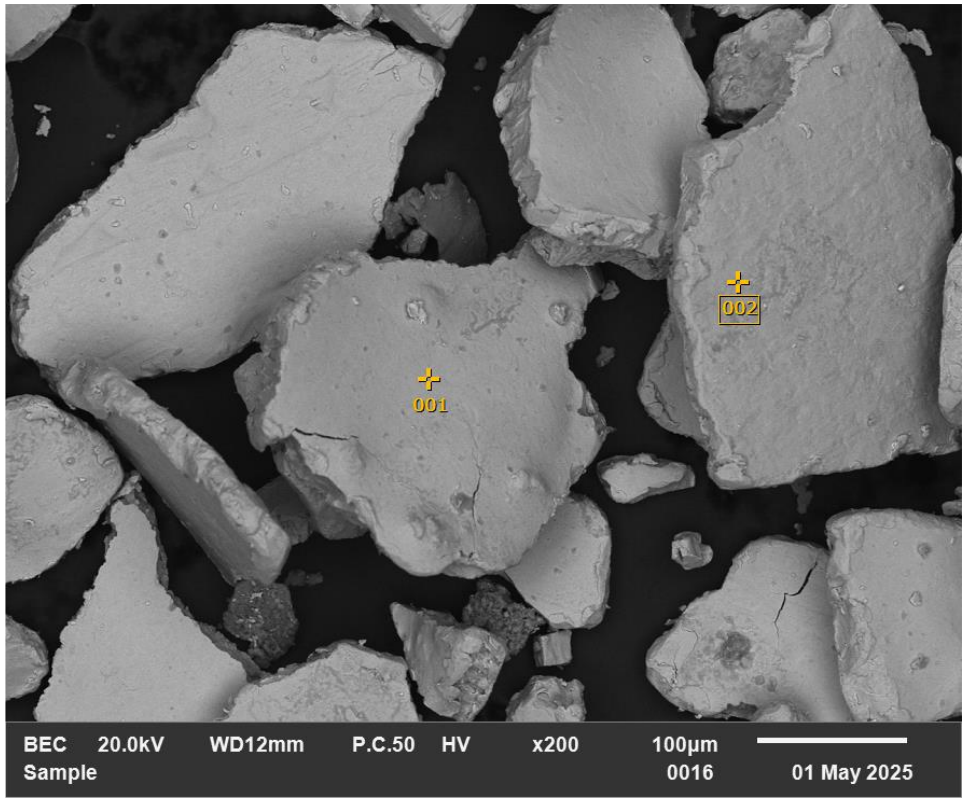


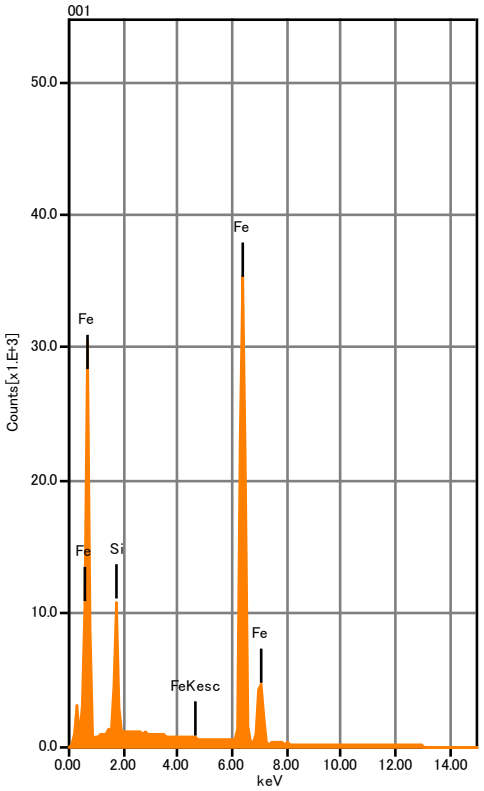
SEM Image of Primary-Pulverized Fe–6.5 wt% Si Ribbon Sample

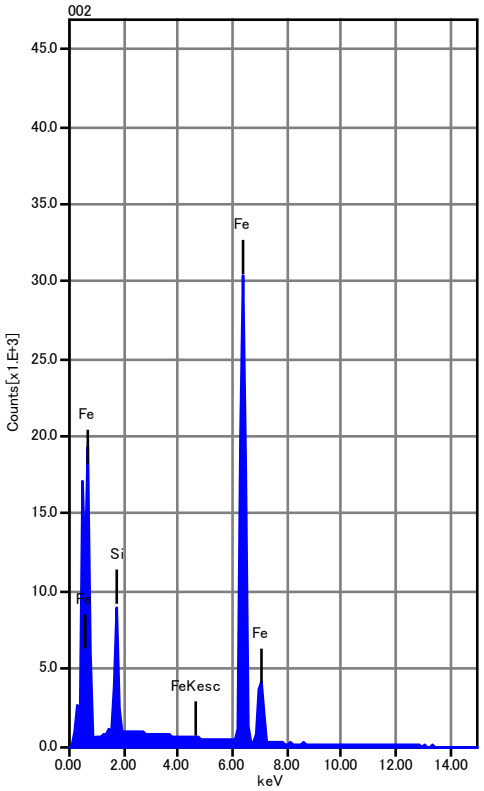


1 L Converge Mill Unit

SEM-EDS Analysis of Primary-Pulverized Fe–6.5 wt% Si Ribbon Sample







Measurement Conditions

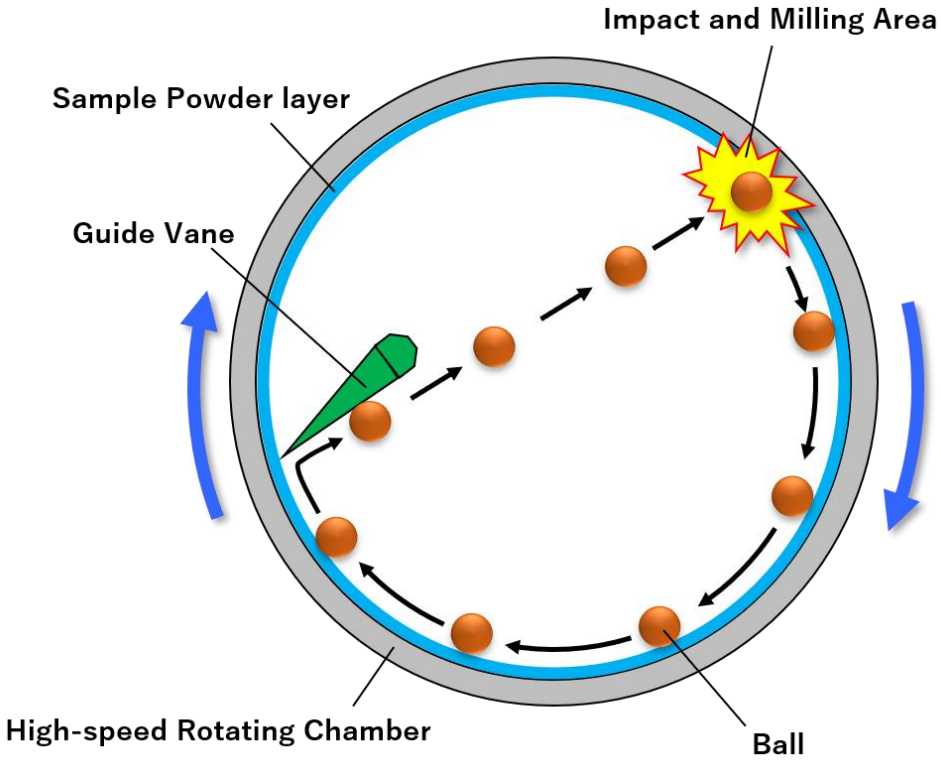
Instrument	: IT100LA
Accelerating Voltage	: 20.00 kV
Beam Current	: ---
Process Time	: T4
Live Time	: 900.00 s
Real Time	: 936.39 s
Dead Time	: 5.00 %
Count Rate	: 1738.00 CPS
Accelerating Voltage	: 20.00 kV
Magnification	: ×200
Measurement Date	: May 1, 2025
Image Resolution	: 1280 × 960 pixels

	Si	Fe
001	7.09	92.91
002	6.86	93.14
Avg.	6.98	93.02
SD	0.16	0.16

Converge Mill Overview

The media balls and sample charged into a rotating vessel are redirected by guide vanes and projected toward the opposite wall. The balls then collide intensively at a localized region with the powder layer formed in the clearance between the guide vanes and the vessel wall, enabling the production of contamination-free fine powder samples.

Details: https://makabe-g.co.jp/products/converging-mill/



SEM Image at a Rotational Speed of 240 rpm

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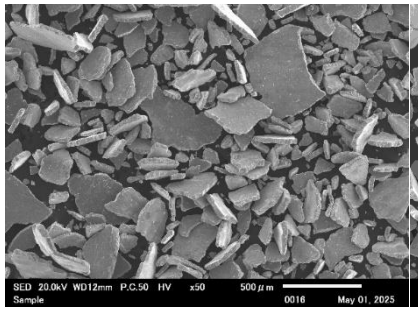
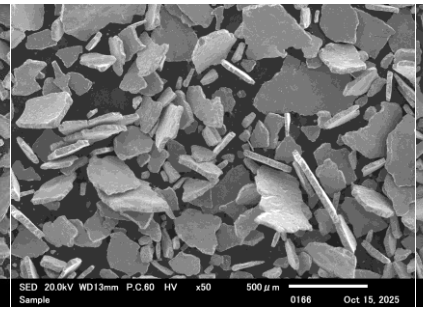
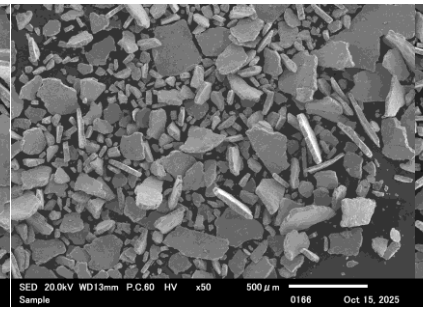
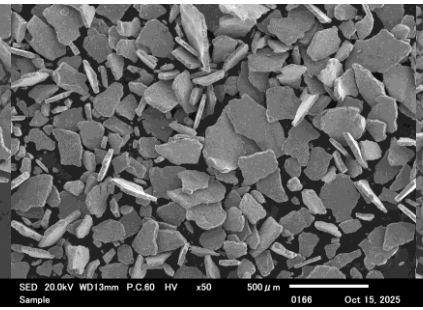
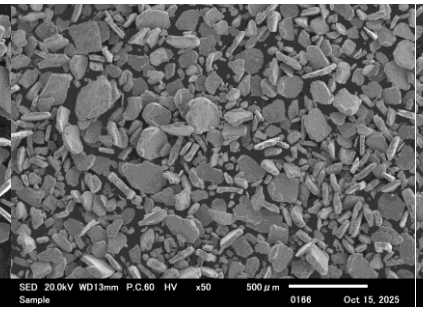
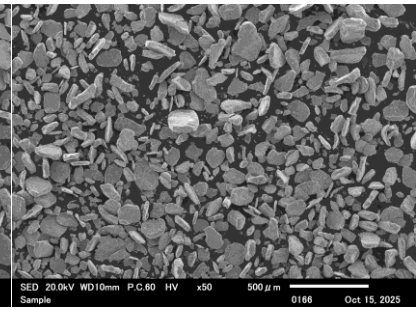
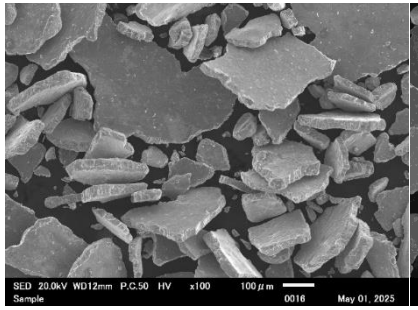
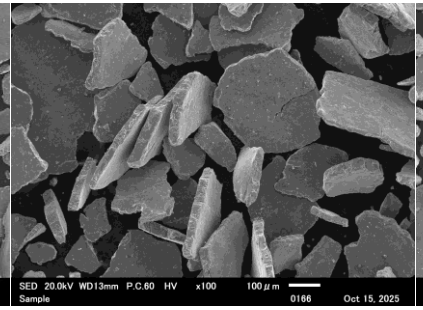
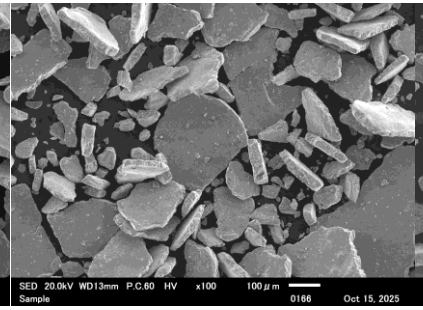
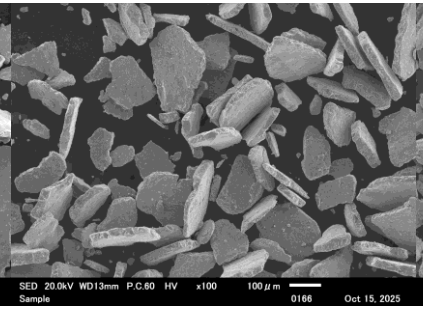
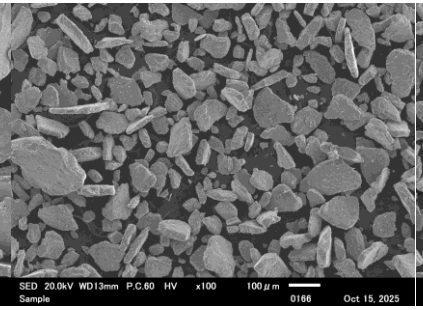
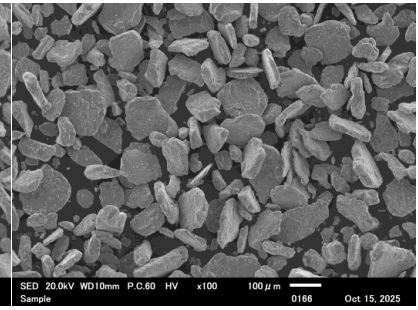
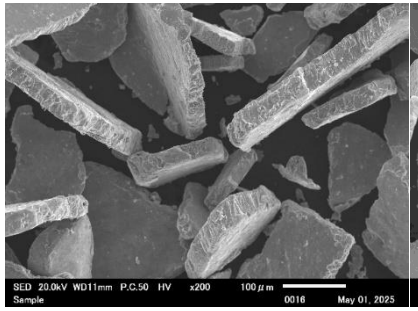
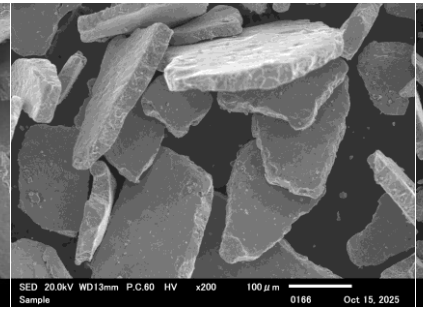
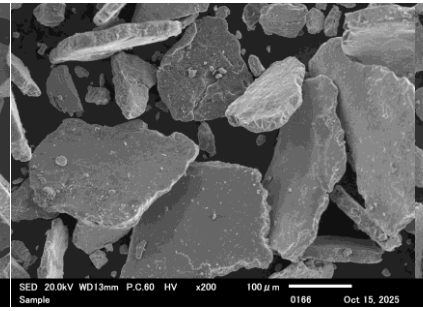
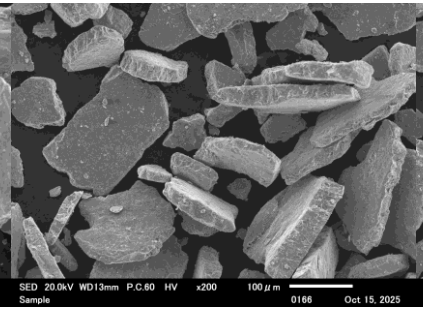
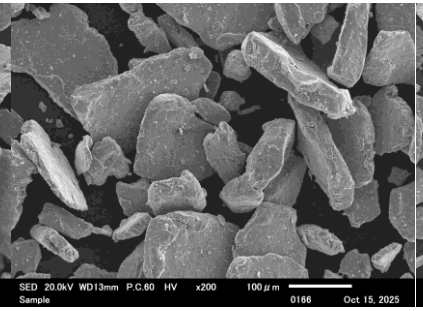
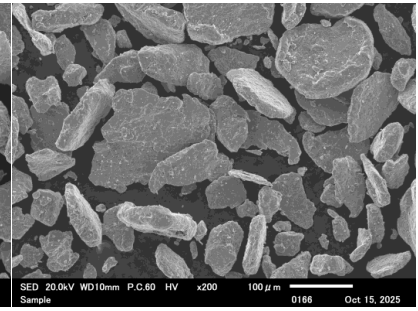
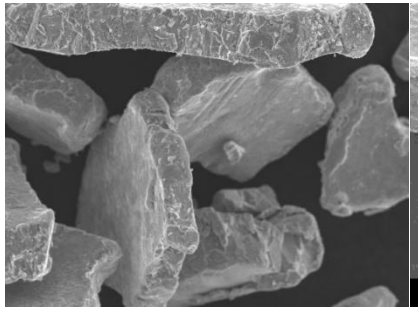
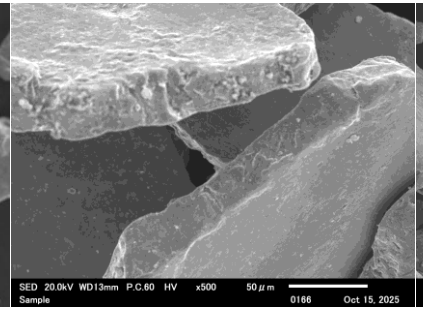
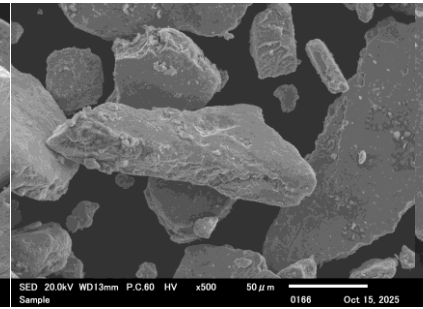
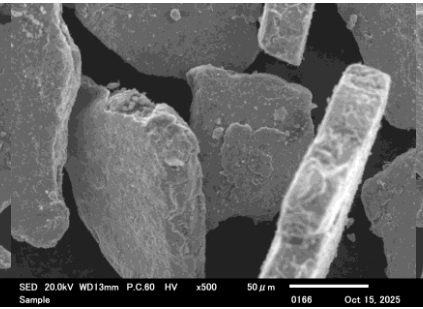
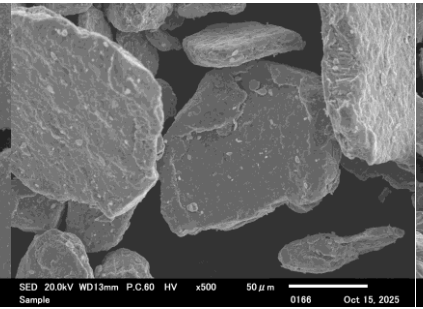
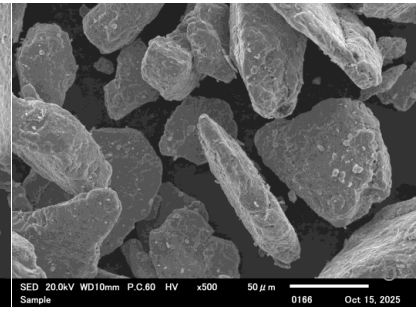
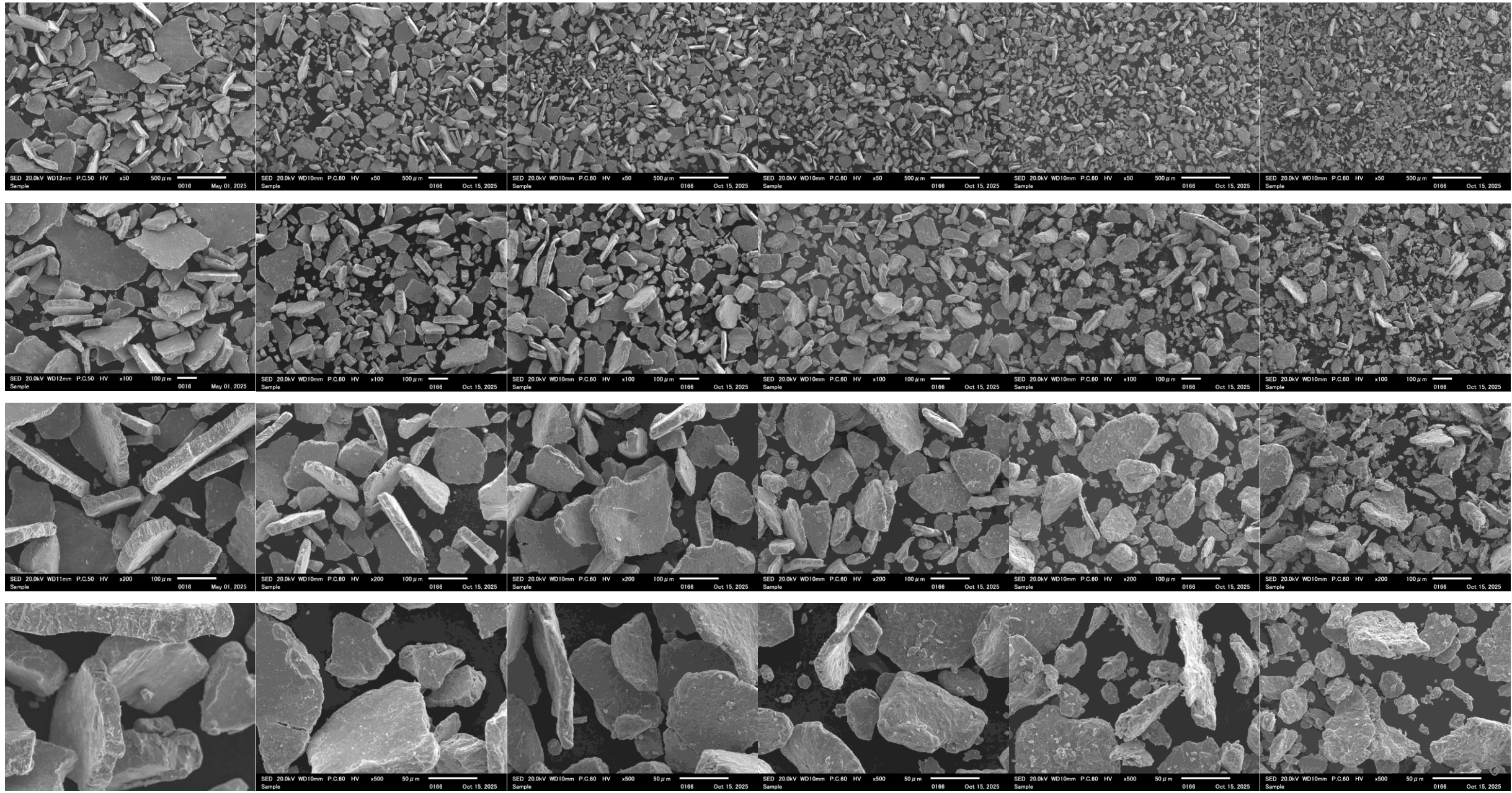
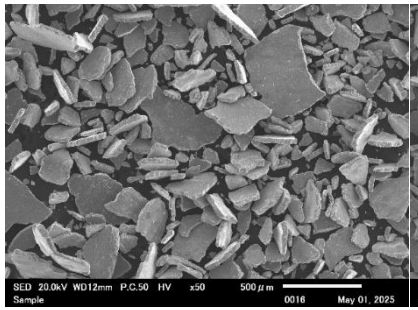
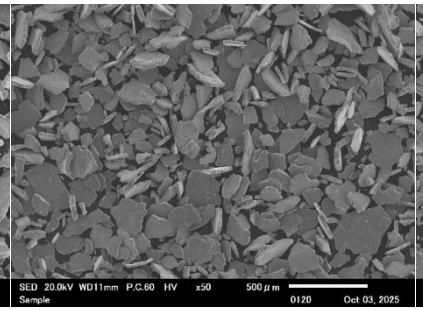
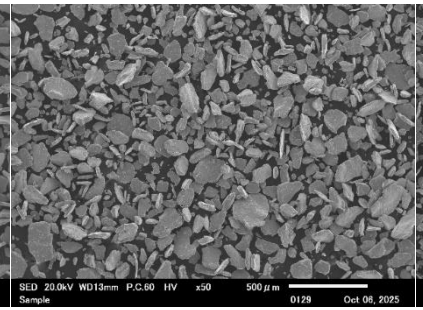
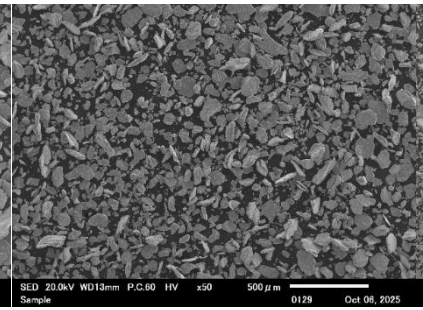
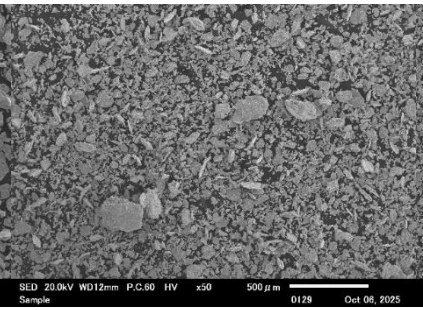
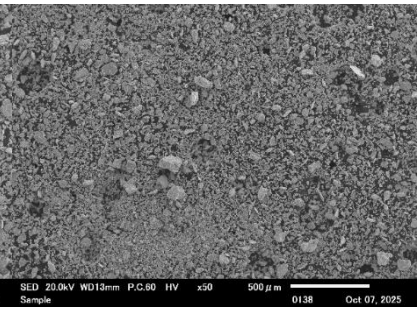
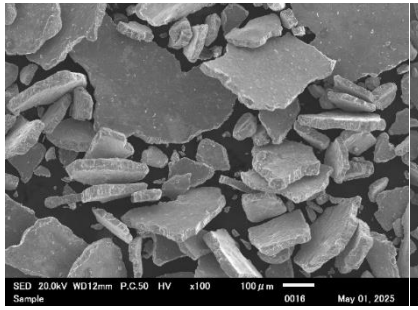
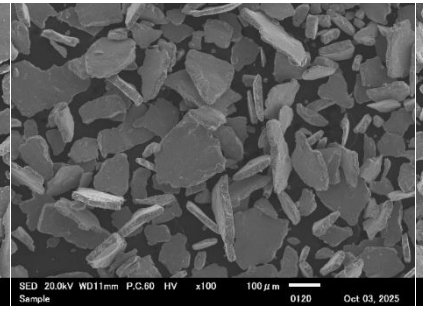
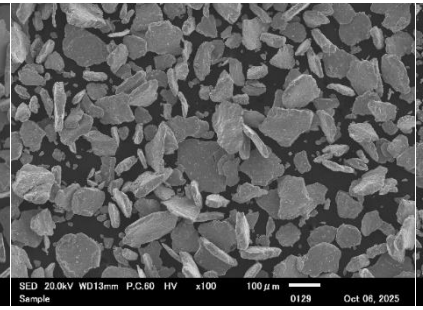
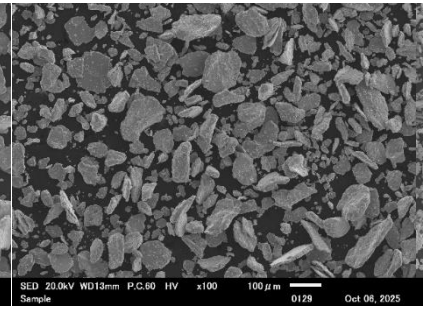
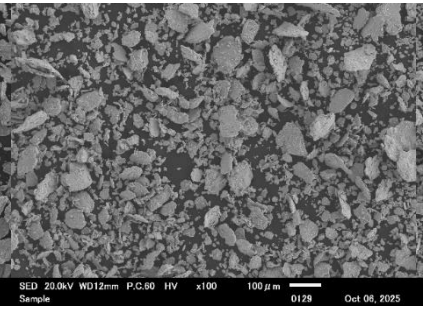
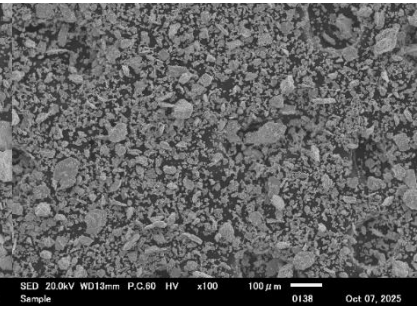
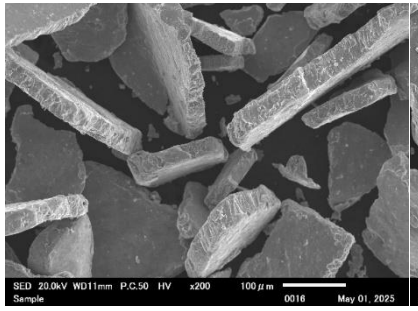
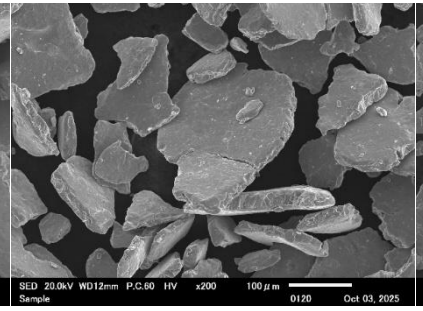
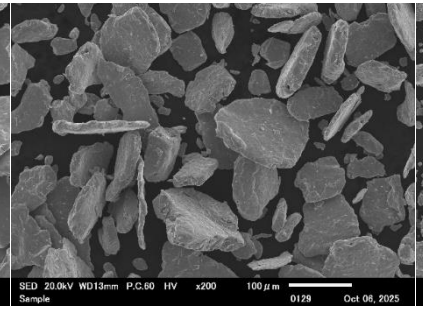
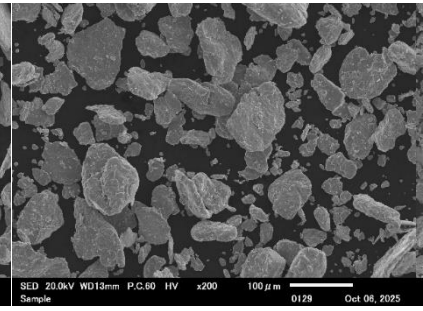
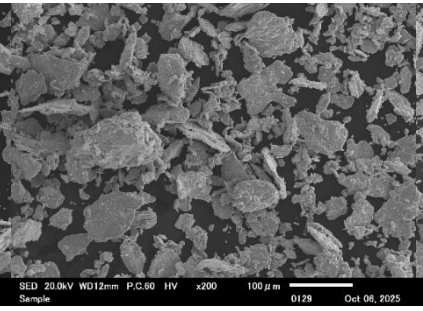
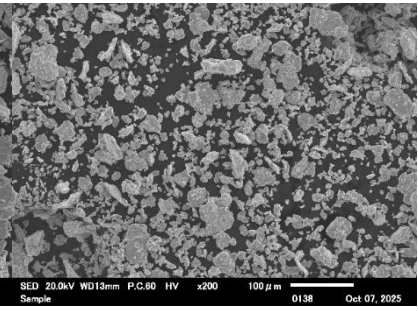
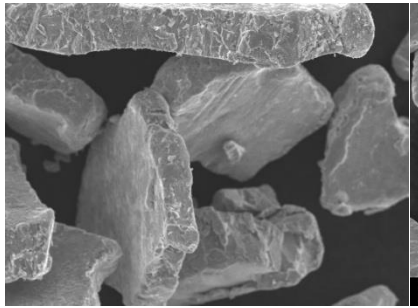
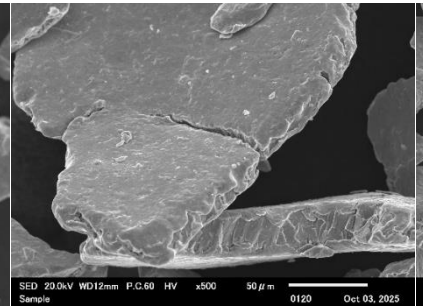
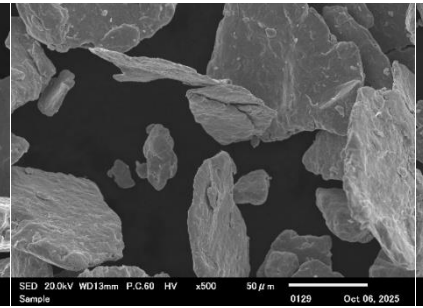
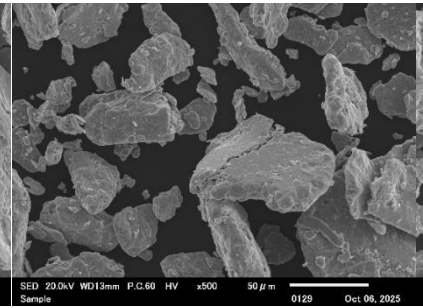
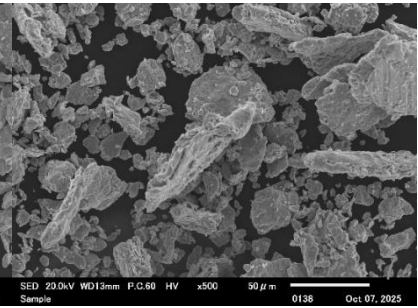
×50						
×100						
×200						
×500						

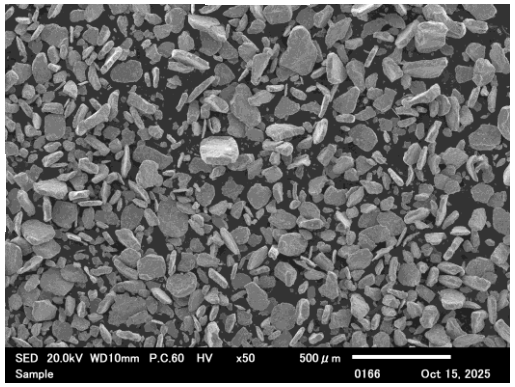
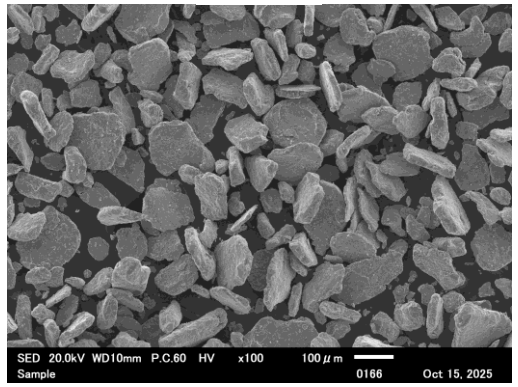
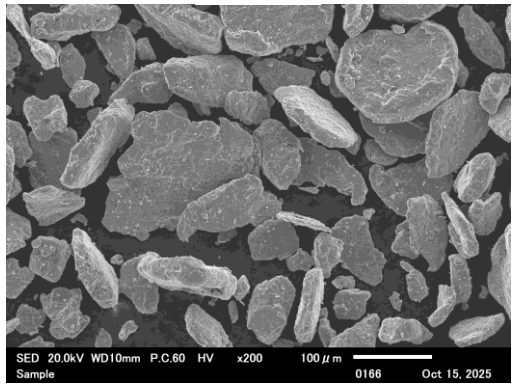
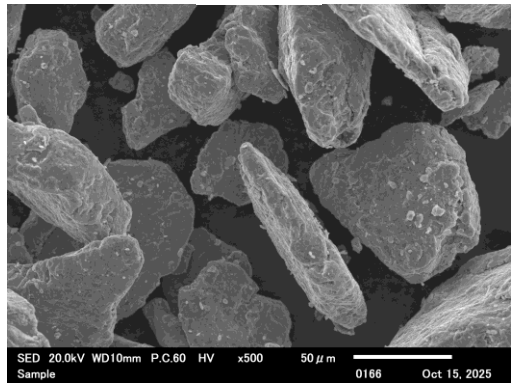
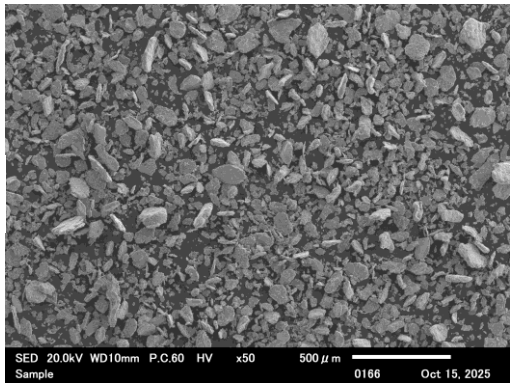
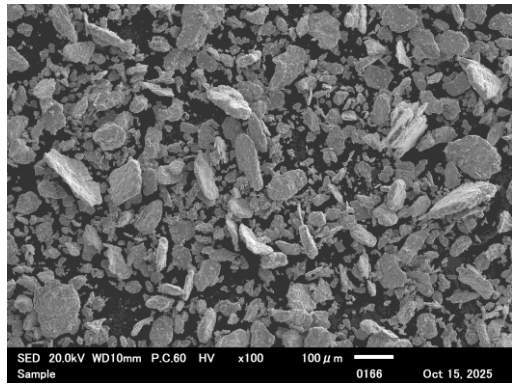
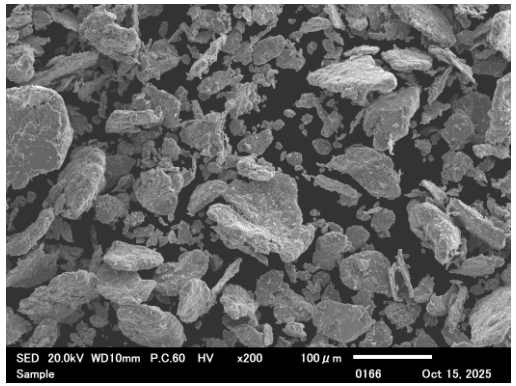
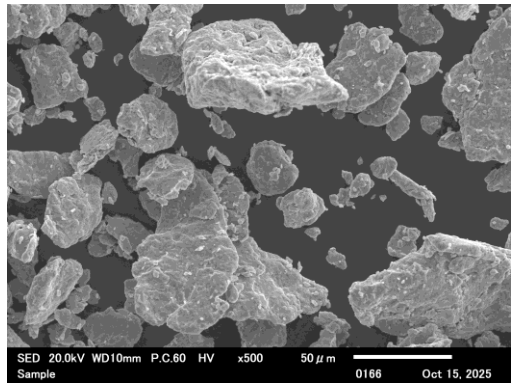
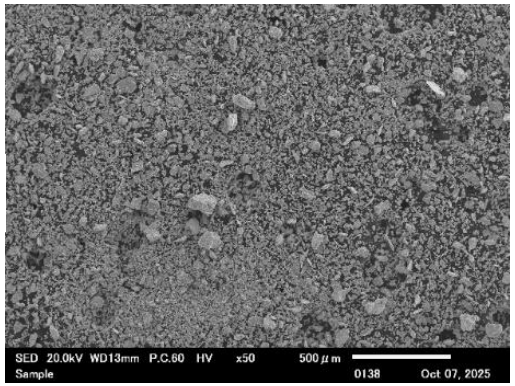
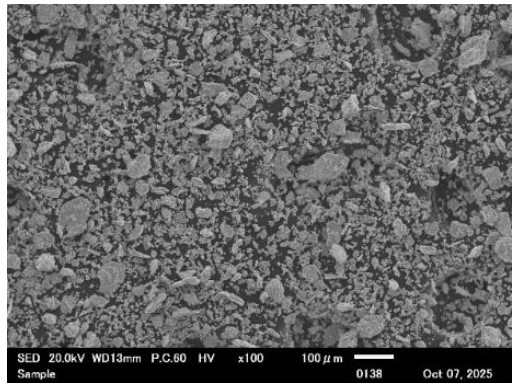
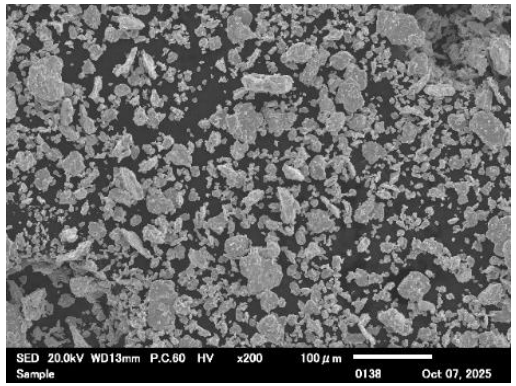
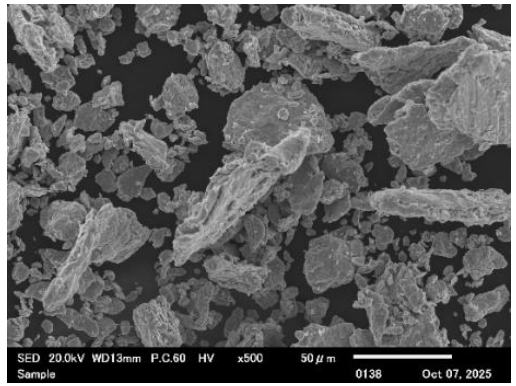
SEM Image at a Rotational Speed of 360 rpm



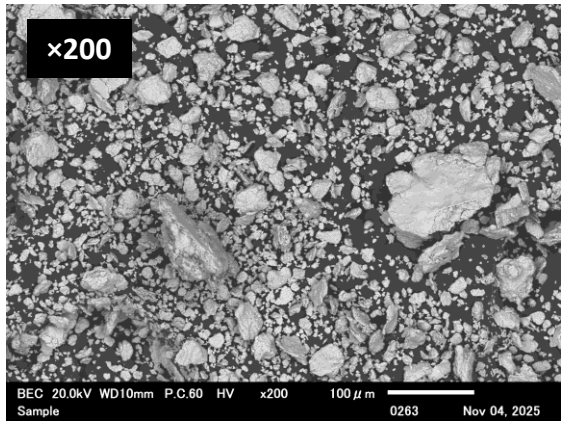
SEM Image at a Rotational Speed of 480 rpm

	As received	Processing time = 1.0 h	Processing time = 2.0 h	Processing time = 4.0 h	Processing time = 8.0 h	Processing time = 12.0 h
×50						
×100						
×200						
×500						

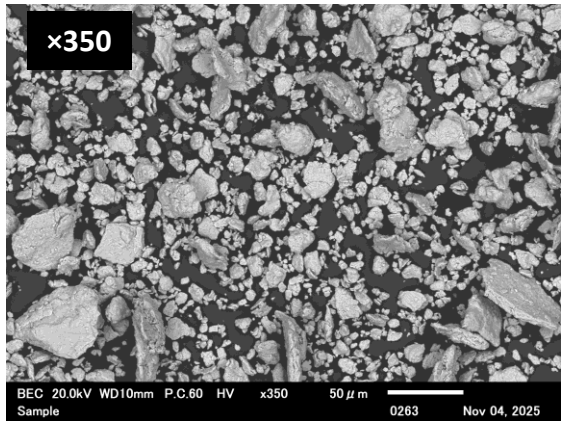
Comparison of SEM Images at a Processing Time of 12.0 h

	×50	×100	×200	×500
240rpm				
360rpm				
480rpm				

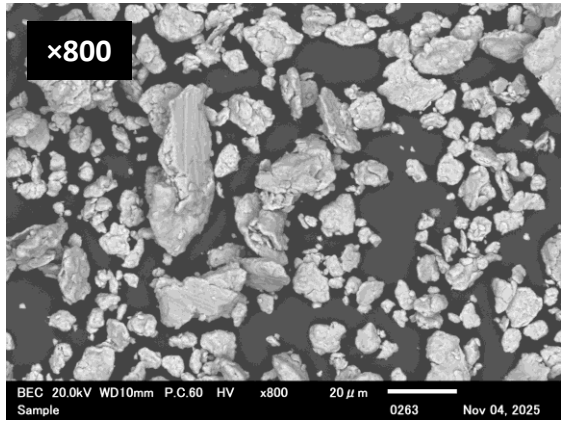
SEM Particle Size Analysis at a Rotational Speed of 480 rpm and a Processing Time of 12.0 h



N= 48,428

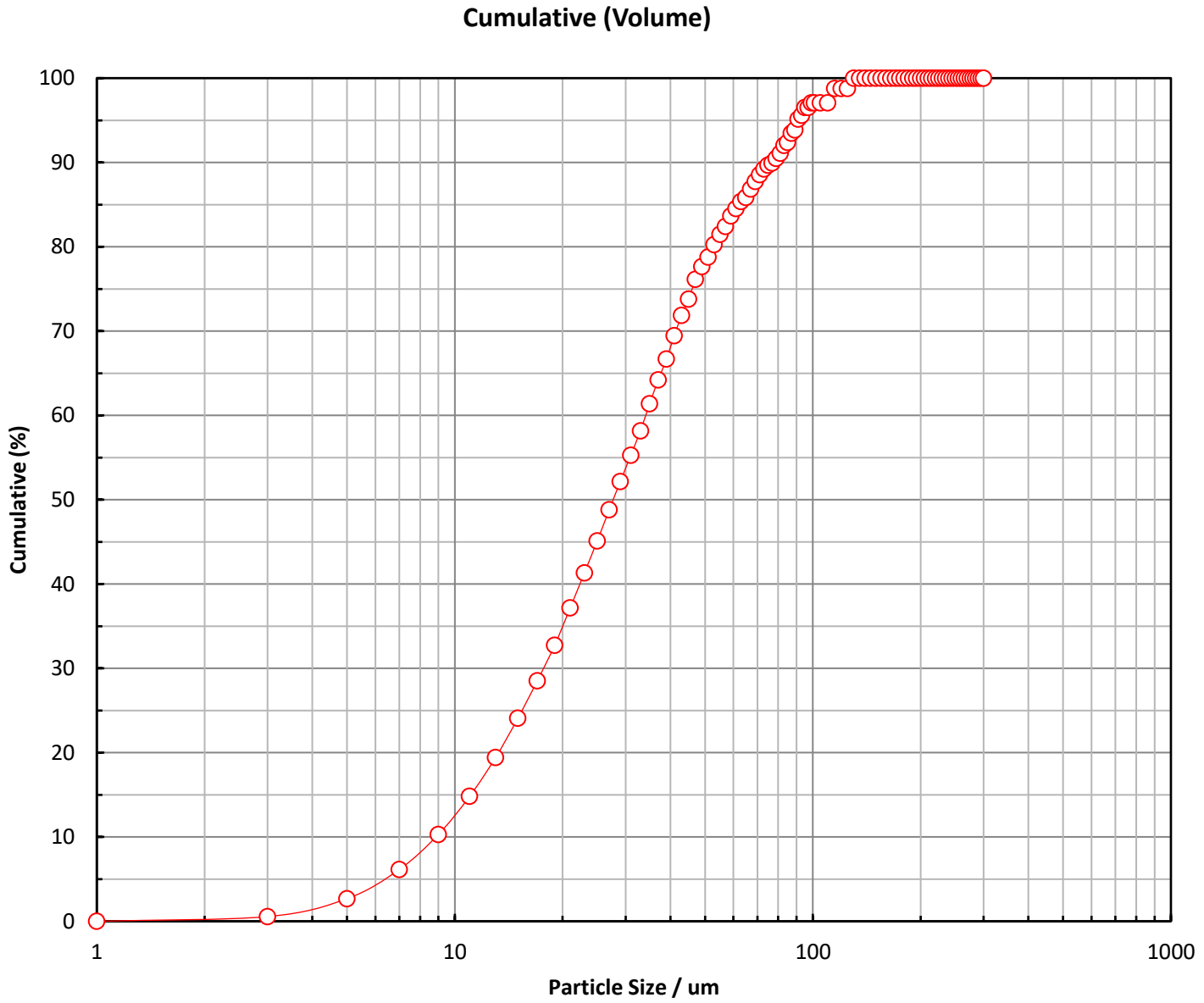


N= 51,895



N= 14,306

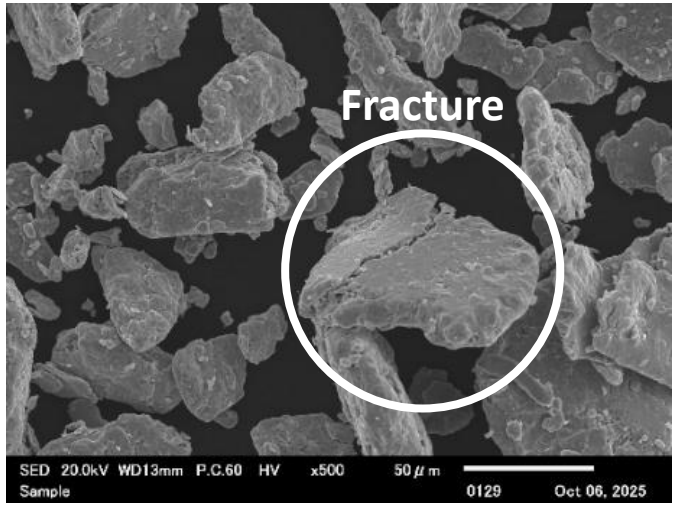
Total N = 114,629



Summary of Additional Pulverization Tests of Fe–6.5 wt% Si Ribbon Fragments Using a Converge Mill

- The ribbon material is relatively brittle, allowing a certain level of pulverization to be achieved even without the use of a dispersant. However, at 480 rpm, agglomerates begin to appear after approximately 8.0 h of processing. To prevent this, the addition of a dispersant is considered necessary.
- SEM observations showed that the particle size decreases with increasing rotational speed at the same processing time.
- The particle size under the processing conditions of 480 rpm for 12.0 h was approximately 28 µm, as determined by SEM-based particle size analysis.
- From the appearance of the powder, it is considered that fracture occurs as the ribbons bend and break at the points where the balls impact. As the particle size further decreases, agglomeration and re-pulverization are thought to occur repeatedly. The addition of a dispersant may contribute to further particle size refinement and the prevention of agglomeration.
- The flattened powder morphology is expected to improve packing density in soft magnetic composites, leading to enhanced magnetic properties such as higher permeability and lower eddy current loss, and enabling high-frequency applications.

Condition after Processing at 480 rpm for 12.0 h



Agglomeration

Re-pulverization