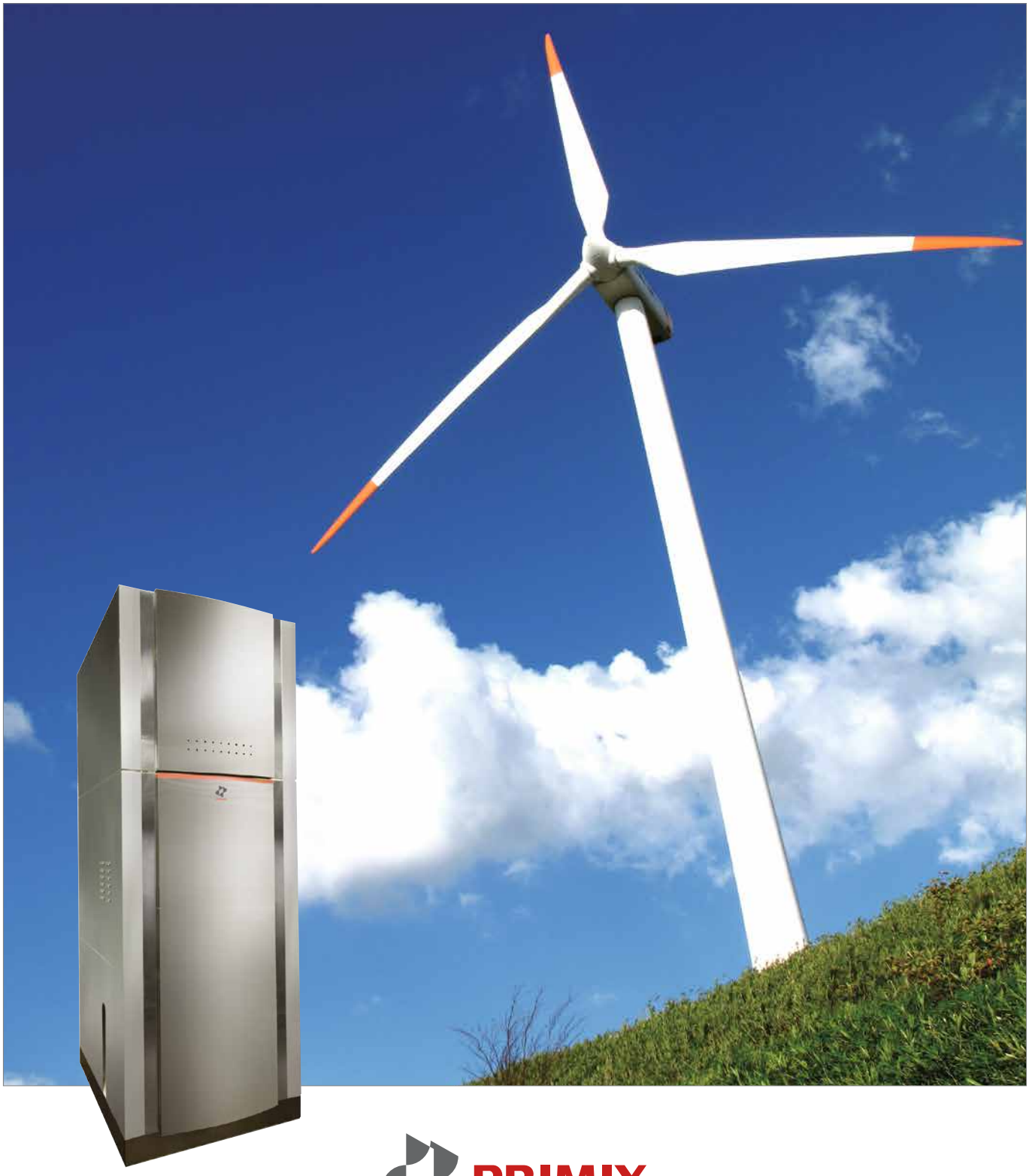
High-Speed, Thin-Film Mixer

FILMIX®

Patented

The World's First. Continuous Manufacturing Technology for Battery Electrode Slurry

CDM Process



PRIMIX

FILMIX® has shattered conventional wisdom when it comes to coating dispersion methods.

This high-speed, thin-film method of dispersion allows for sharp particle size distributions and uniformity in dispersions of nano-meter sized particles that has been impossible to achieve using conventional methods of dispersion.

Construction and Dispersion Principle of Filmix

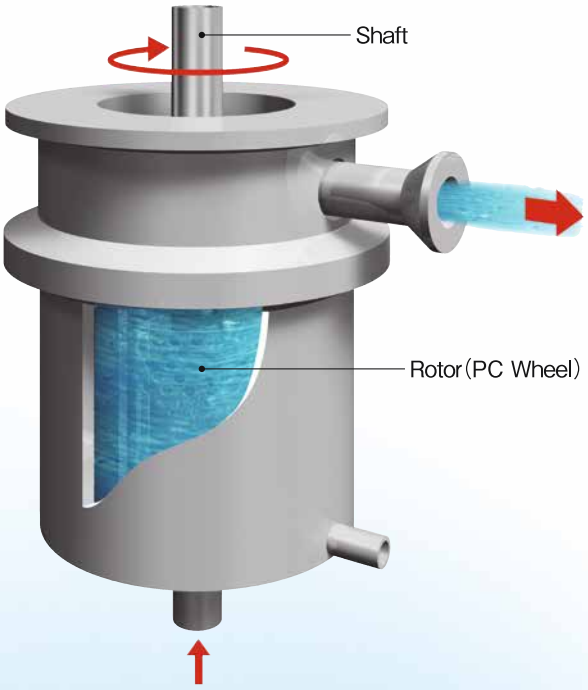
Construction

The FILMIX has 5 main parts: a rotating shaft and cylindrical PC wheel, a stationary vessel, discharge weir, and overflow vessel. Because the FILMIX does not require the use of any mixing media, it is very easy to clean, maintain, and repair.

Mixing Mechanism and Features

FILMIX is different than conventional mixers because it moves fluid in a special way. The cylindrical PC wheel rotates at high speed while fluid is fed from the bottom of the vessel. When fluid is fed continuously, it is pulled toward the inside wall of the vessel by centrifugal force. Because the vessel wall is stationary, the film formed on the wall flows at a speed of 50m/s, creating a strong shear stress in the material. This "elongated flow pattern" of the rotating thin film is where the FILMIX disperses material into fine particles and droplets. Two directional flow patterns-up and down, and at the vessel wall where the rotating flow of material spins with the PC wheel-create a turbulent flow, allowing for a uniform dispersion in a very short period of time.

Dispersion Principle



Applications

Cosmetic: Sunscreen Creams, Lotions, Emulsions, Creams
Pharmaceutical: DDS Medication, Liposomes, Lipid Emulsions
IT: Ceramic Materials, Metallic Materials, Display Materials, Encapsulant, Capacitors, Conductive Pastes
Chemical: Inks, Toners, Resins, Coating Materials
Battery: Lithium-Ion Batteries, Fuel Cell Electrodes, Electric Double Layer Capacitors

The innovative technology of the FILMIX has revolutionized dispersion.

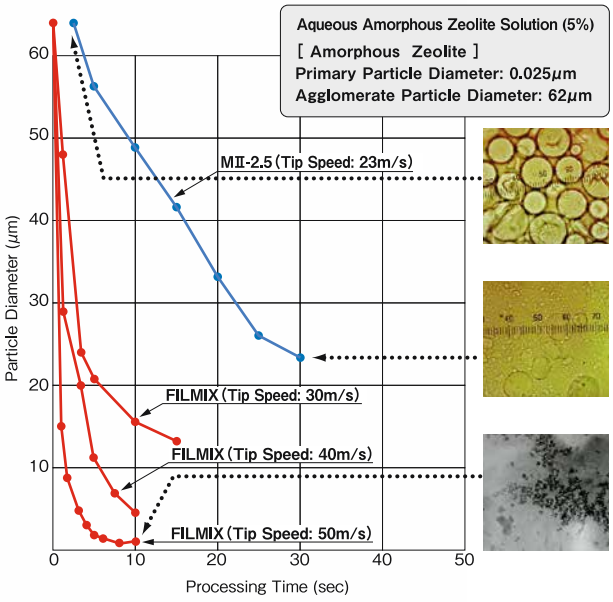
Inside the thin film, a uniform and consistent level of energy is imparted to the material in a way not possible with conventional mixers. The method results in a very sharp distribution curve in particle size and can mix at the nanometer level. With this method of mixing, sorting material by particle size is not necessary as it is with conventional methods.

Characteristics of Mixing by Filmix

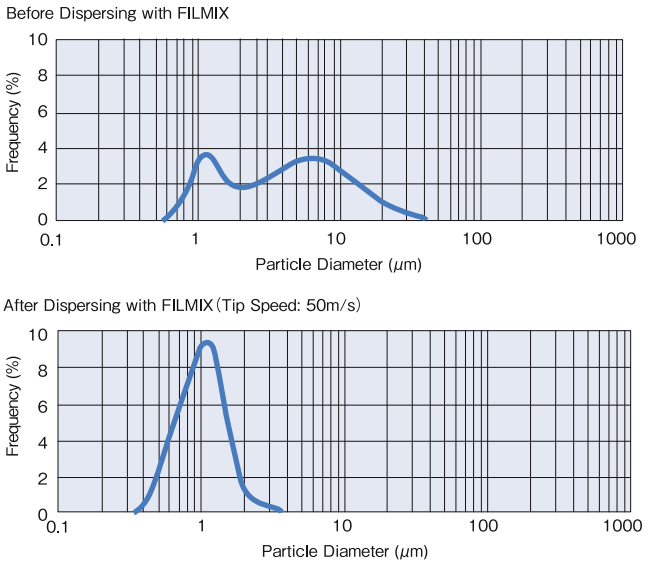
1 A Sharp Distribution Curve in Particle Size by Uniform Mixing

Dispersion

An Example of Dispersion: Amorphous Zeolite

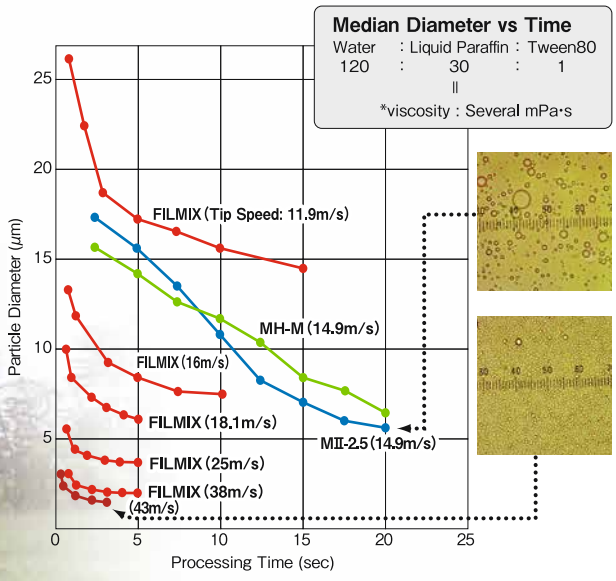


An Example of Dispersion: Titanium Oxide for Photocatalyst

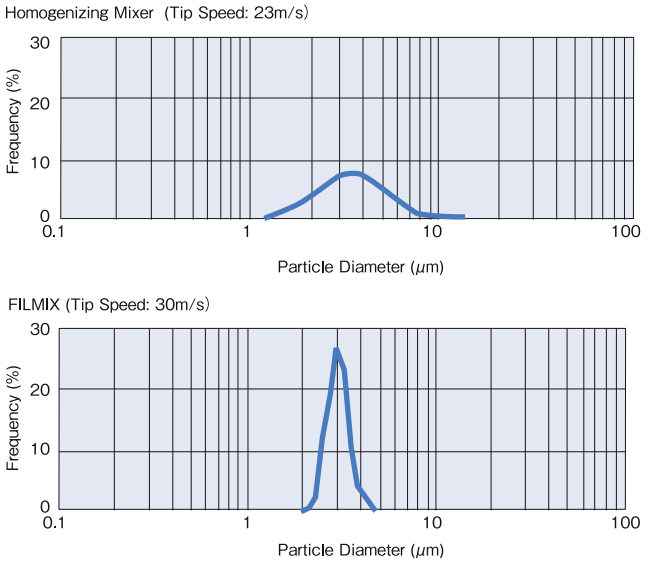


Emulsification

An Example of Dispersion: Liquid Paraffin



An Example of Dispersion: Comparision with Homogenizing Mixer

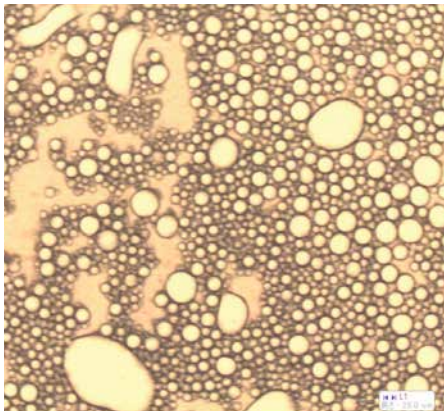


Water : Liquid Paraffin : Tween80 = 120:30:1

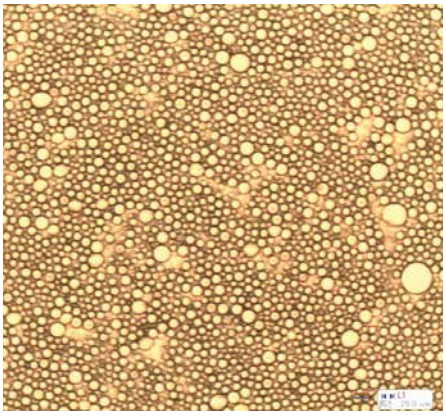
2 New Possibilities in Engineering Particles

High Precision Dispersion

By Homogenizing Mixer (Tip Speed: 23m/s, Time: 20min)

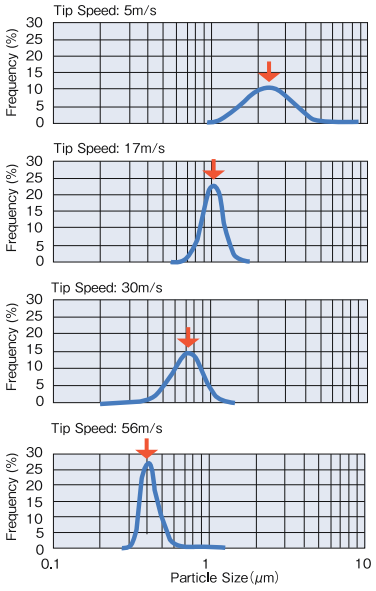


By Filmix (Tip Speed: 23m/s, Time: 60sec)



Possible to optimize the level of dispersion to the material

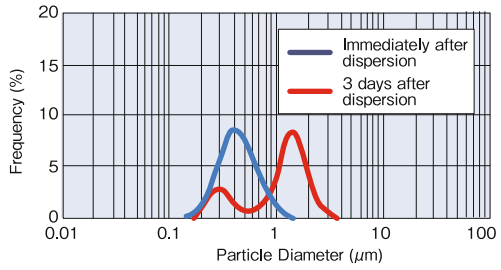
Water : Liquid Paraffin : Tween80 = 120:30:1



3 Stable Dispersion without Re-Agglomeration

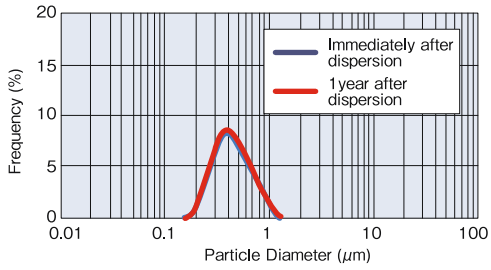
Dispersion Stability

Dispersed Using a Bead Mill



Material = Bi_2SO_3

Dispersed Using FILMIX



Material = Bi_2SO_3

PC Wheel Tip Speed = 50m/s

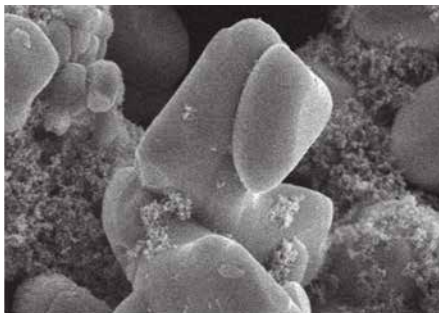
Processing Time = 60sec

4 Dispersion without Damage to Particles

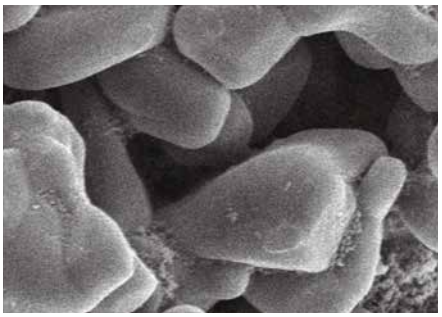
Shear force dispersion for the next generation of advanced particulate materials

LCO (Lithium-Ion Battery Cathode Material)

Pre-Mixing



FILMIX (Tip Speed: 50m/s, 30sec)



Through the innovative use of shear force in the FILMIX, the next generation of particulate material can be dispersed without damaging the crucial particle surface.

The new continuous manufacturing technology: CDM Process for lithium ion battery electrode slurry

CDM Process Structure

PRIMIX has developed a new production process, the CDM Process (Continuous Dispersion Mixing Process), tailored for the mass production of rechargeable lithium-ion batteries.
The CDM Process is
a completely new continuous production system which uses the FILMIX, a high-speed thin-film mixer, to manufacture electrode slurries.
The CDM Process
enables optimized dispersions of the latest battery materials, improving battery performance and contributing to the improvement of product quality and cost-competitive battery manufacturing.

The CDM Process charges the electrode materials to the pre-mixer vessel, then feeds the pre-mixed slurry with a pump to the FILMIX continuously at a constant rate.
The slurry dispersed by the FILMIX first passes through a buffer tank, then undergoes continuous cooling and deaeration before it is sent to the storage tank.
In addition to the quality improvement of the electrode, the CDM Process reduces factory size and the number of workers, and is automated, contributing to battery manufacturing that can overcome the intense price competition of the battery market.

Comparison of CDM and Batch Mixing Processes

The following chart compares costs of the CDM and batch mixing processes. All values are scaled such that the batch mixing costs are 100.

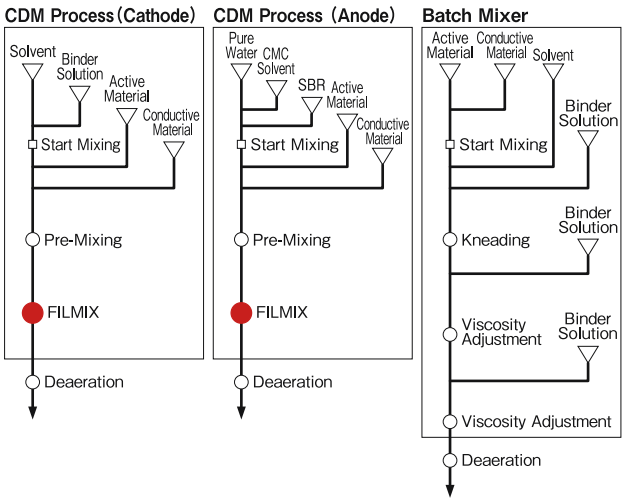
Comparison of Manufacturing Cost and Environmental Load

	Factory Space (m^2)	Electricity Consumption (kWh / day)	Labor (man-hours per day)	Investment (our products)
CDM Process Production Capacity: 21,000L/day	53	33	21	28
Batch Mixer Production Capacity: 20,000L/day	100	100	100	100

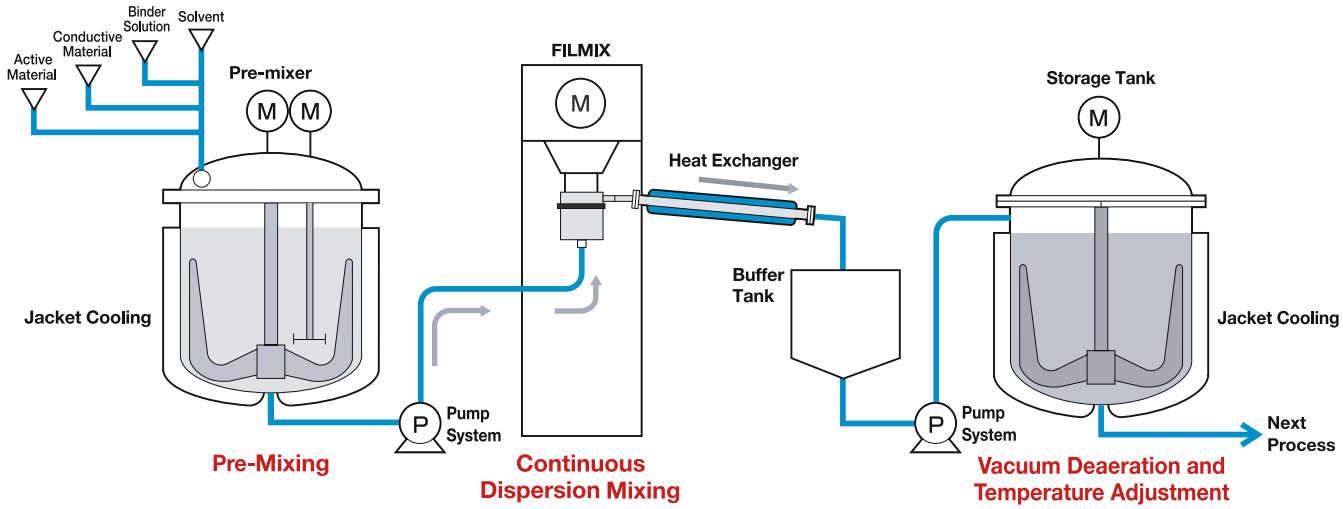
(Relative values)

Simplicity of the CDM Process

The mixing step of the CDM Process has been simplified, making possible the production of highly reproducible electrode slurries without a practiced technician.



Powder Charging



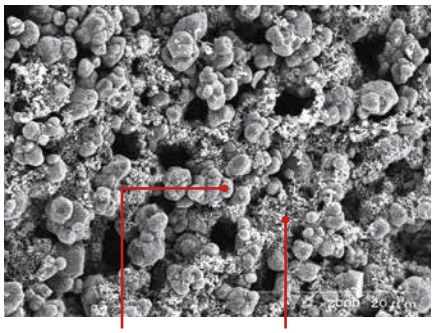
Achieving high quality manufacturing of electrode slurry

1 Uniform Dispersion

The smaller the particle of active material (from nano-sized to a few microns), the more difficult dispersion becomes with a conventional batch mixing process. The unique and innovative dispersion mechanism of the FILMIX makes uniform dispersion possible.

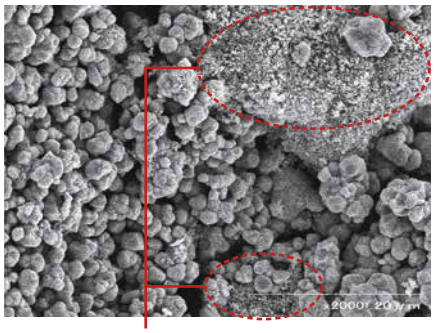
Dispersion of Lithium Ion Battery Electrode

FILMIX Material: LFP



Active Material Conductive Material

Conventional Batch Mixer

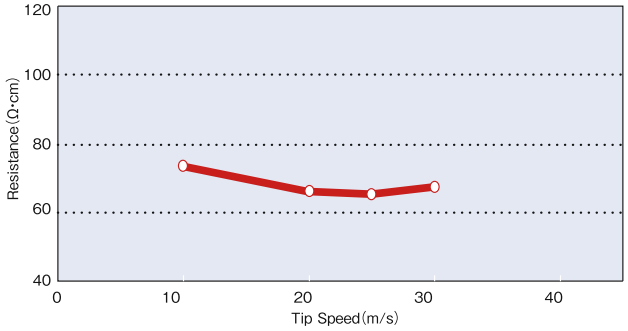


Agglomerated Conductive Material

2 Finding Optimal Dispersion Conditions through Testing

The lowest possible electrical resistance of coated slurry can be achieved by simply changing the PC wheel speed. This functionality makes it easy to determine the optimal conditions for dispersion.

Dispersion Conditions and Electrical Resistance of Coated Slurry



Method of Measurement: Four-terminal method
Conductive Material: AB
Active Material: LFP

3 Reliable Reproducibility of Viscosity

CDM process allows reproducibility of slurry viscosity in this simple process and quantifies operating conditions allowing for stable product quality.

(a) NMP-based (Cathode)

Run	Viscosity (mPa·s)	Temperature (℃)
1	5800	25
2	5900	25
3	6100	26
4	6100	26
5	6000	25
6	6100	25
7	6000	26
8	6200	25
9	5900	25
10	6000	25

Mean Viscosity: 6010mPa·s
Standard Deviation: 113.6mPa·s (1.89%)
Electrode Material: LCO

(b) Water-based (Anode)

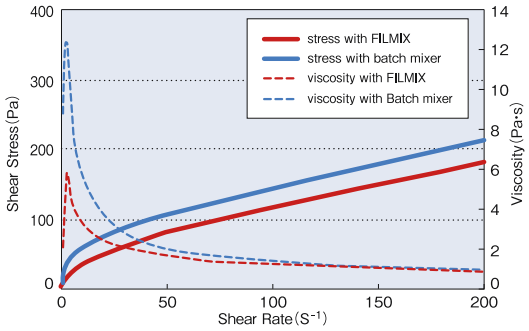
Run	Viscosity (mPa·s)	Temperature (℃)
1	4900	21
2	5200	20
3	5200	21
4	5100	21
5	5000	21
6	5000	21
7	5000	21
8	5000	21
9	5100	21
10	5200	20

Mean Viscosity: 5070mPa·s
Standard Deviation: 100.5mPa·s (1.98%)
Electrode Material: Graphite

4 Improved Slurry Rheology and Stability

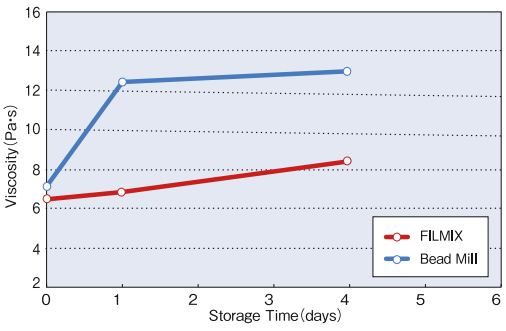
Dispersions with FILMIX have a unique functionality that allows for a high level of control over the rheologlcal properties of the slurry to be manufactured. Adjustments can be made to obtain the optimal slurry to be used in the electrode coating process. It is also possible to create an electrode slurry with superior stability.

Rheological Properties (FILMIX vs Batch mixer)



Electrode material: LFP

Viscosity Stability (FILMIX vs Bead mill)



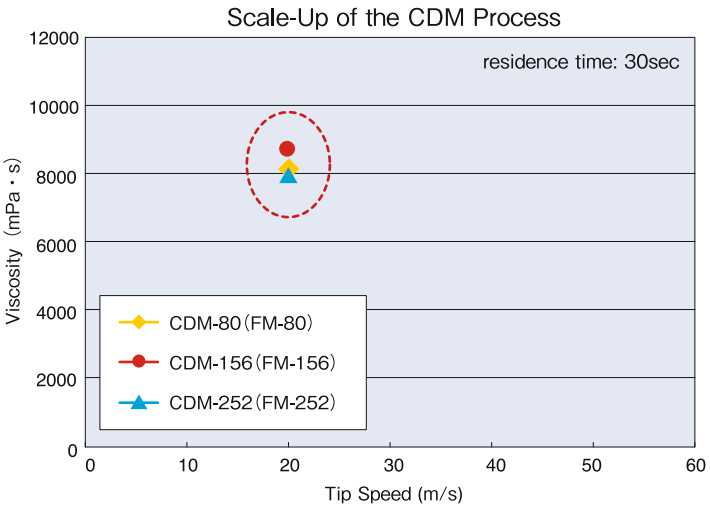
Electrode material: LFP

Fine example of electrode slurry

Ease of Scale-up with the CDM process

A unique feature of the FILMIX is the ease of scaling-up for mass production. Since the dispersion conditions are determined by the mixing time and PC wheel speed, it is easy to replicate conditions when expanding production to larger equipment.

The following is a comparison of the production capacity per hour of FILMIX models: 30L for CDM-80, 240L for CDM-156, 960L for CDM-252. Simply set the same mixing time and wheel speed to achieve the same viscosity with some very fine adjustments.



CDM Process Line Up

CDM125 through CDM252 are for production. CDM80 is for R&D and Pilot Production.

The CDM Process has five models to meet production levels.

	CDM-80	CDM-125	CDM-156	CDM-220	CDM-252
Pre-Mixer	Combi Mix Model 150	Combi Mix Model 500	Combi Mix Model 1000	Combi Mix Model 2000	Combi Mix Model 4000
FILMIX	FM-80	FM-125	FM-156	FM-220	FM-252
Residence Time	30 sec	30 sec	30 sec	30 sec	30 sec
Operating Time/day	Combi Mix Model 150 (6-batch) + FM-80 (24 hour operation)	Combi Mix Model 500 (6-batch) + FM-125 (24 hour operation)	Combi Mix Model 1000 (6-batch) + FM-156 (24 hour operation)	Combi Mix Model 2000 (6-batch) + FM-220 (24 hour operation)	Combi Mix Model 4000 (6-batch) + FM-252 (24 hour operation)
Capacity(approx.)	700L/day	2,800L/day	5,700L/day	12,000L/day	23,000L/day

Optional Ceramic PC Wheel and Vessel

Metallic contamination in the manufacturing of electrode used in energy devices dramatically decreases performance, output, and life of the energy device. Optional specifications allow for wetted parts - PC wheel and vessel - to be made of ceramics.

Contact

Bühler AG
Headquarters
CH-9240 Uzwil, Switzerland
Tel +41-71-955-3491 Fax +41-71-955-3149
grinding.dispersion@buhlergroup.com
www.buhlergroup.com

Bühler Inc.
North America
40 Whitney Road
Mahwah, NJ 07430, U.S.A.
Tel +1-201-847-0600
gdnorthamerica@buhlergroup.com

PRIMIX Corporation
Headquarters
8-16-43, Ebie, Fukushima-ku, Osaka 553-0001, Japan
Tel +81-6-6458-7531 Fax +81-6-6458-7850
mail@primix.jp
www.primix.jp

PRIMIX Corporation
North American Sales Rep.
182 Beachfield Dr. Battle Creek, MI 49015, U.S.A.
Tel +1-269-660-9910
TracyMiller@primix.jp