APPLICATIONS OF UNION PROCESS MILLS

FOR THE LITHIUM-ION

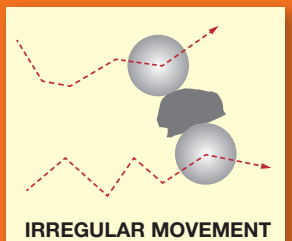
BATTERY INDUSTRY

Grinding Principle

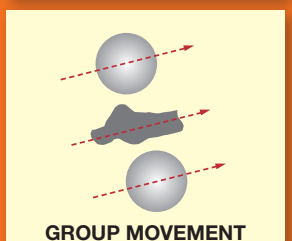
The Attritor is a high energy internally agitated media mill. The Attritor utilizes a rotating agitator shaft which efficiently imparts energy to the grinding media, creating kinematic porosity and random media movement throughout the entire grinding chamber.

Both impact and shear forces are created in this “chaotic” state of motion. The grinding media and particles move randomly, colliding and impinging upon each other resulting in highly efficient grinding and/or thorough and complete dispersion.

Movement of media and particles



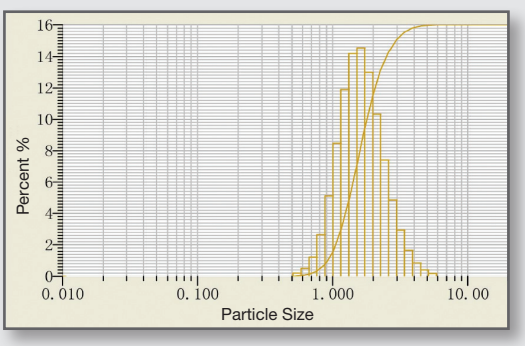
IRREGULAR MOVEMENT



GROUP MOVEMENT

Case Study

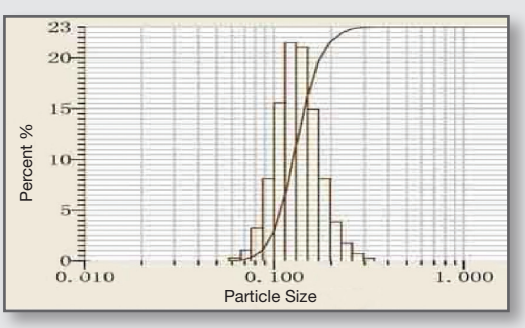
S-Attritors to grind lithium iron phosphate precursor material:



Particle Size Analysis After Milling in S-Attritor

Material: Lithium iron phosphate precursor
Feed size: D50=100µ
End size: D50<2µ
Grinding time: 1 hr
Solvent: Alcohol

DMQ-Mills to grind lithium iron phosphate precursor material:



Particle Size Analysis After Milling in DMQ Mill

From S-Attritor:
Material: Lithium iron phosphate precursor
Feed size: D50<2µ
End size: D50<150nm
Grinding time: 3 hrs
Solvent: Alcohol

Lithium Iron Battery applications utilize a 2 phase process:

Phase 1 – Lithium Iron Phosphate *Precursor* Application (Wet or Dry):

For both wet and/or dry milling applications in the lithium iron battery industry, the S-series Attritors are utilized in a 2-phase process. The first phase involves grinding and thoroughly dispersing coarse powder(s) down to the 1-3 um particle size range in an S-series mill from Union Process, Inc. Phase 1 processes can be either “wet” utilizing the ***S-series*** Attritor or “dry” utilizing the ***SD-series*** Attritor.

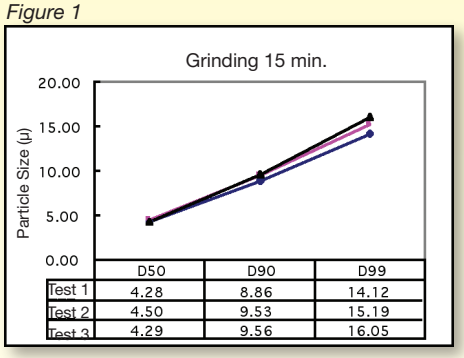
Phase 2 – Lithium Iron Battery *Finished* Material Application (Wet):

The ***DMQ series*** horizontal circulation mill is utilized in phase 2 for complete and thorough dispersion of agglomerated material to the primary particle size range of 200-300nm.

Repetitive comparison of grinding tests for lithium iron phosphate precursor:

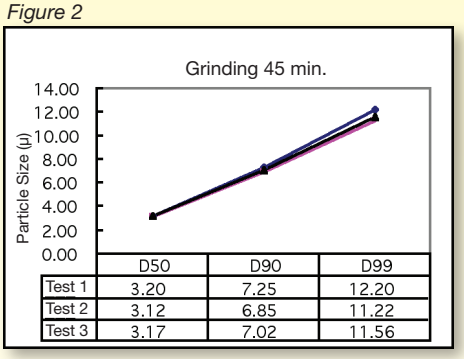
Figures 1 and 2 display consistency and repeatability of milling results from the S-Attritor. The D50 is within the 5% range, and the D99 is within the 10% range.
Note: *with an increase in grinding time, the degree of repeatability is increased as well. Union Process, Inc., mills can produce fast, efficient, and repeatable results for the lithium iron battery industry.*

Figure 1



	D50	D90	D99
Test 1	4.28	8.86	14.12
Test 2	4.50	9.53	15.19
Test 3	4.29	9.56	16.05

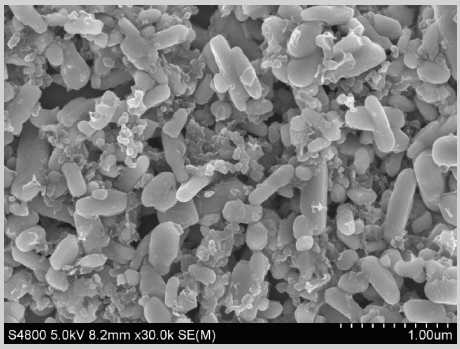
Figure 2



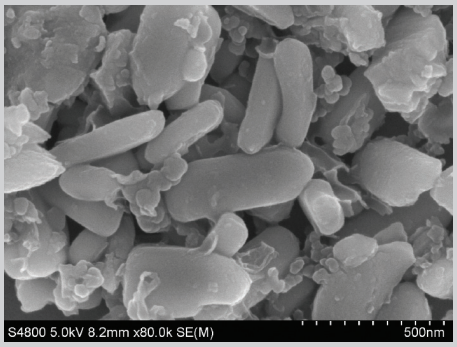
	D50	D90	D99
Test 1	3.20	7.25	12.20
Test 2	3.12	6.85	11.22
Test 3	3.17	7.02	11.56

DMQ-Mill™ Horizontal Circulation Mixes and Disperses Finished Battery Material:

Material: Lithium iron phosphate + conductive agent
Feed size: D50=2-3µ
End size: D50<200nm
Processing time: 0.5 hr
Solvent: NMP



SEM (1µ) of lithium iron phosphate after processing for 0.5 hr



SEM (0.5µ) of lithium iron phosphate after processing for 0.5 hr

S-Attritor Features *(Wet)*

- Adaptability: Premixing is not necessary when processing multiple components. The S-Attritor can process slurries with a maximum viscosity of up to 30,000.
- Circulation pump: Circulation during processing improves grinding efficiency and achieves uniform distribution of the slurry.
- Variable speed system: Variable mill speed allows versatility to optimize processing conditions.

S-series

SD-Attritor Features *(Dry)*

- Variable speed system: Variable frequency drive allows versatility to optimize processing conditions.
- Powders are easily added through top of mill and discharged through a grid at bottom of mill.
- Allows for grinding under inert gases or the introduction of liquid nitrogen for cooling.

SD-series

DMQ-Mill™ Features *(Small Media or Bead Milling)*

- High energy density: Patented design of Delta disks create forced centrifugal grinding inside the mill; the speed is higher than 15 m/sec.
- Narrow particle size distribution: The mill tank is filled with small media and operated at a very high circulation rate. Produces very narrow particle size distribution of the processed material.
- Super fine grinding media are used: As fine as 0.1-1 mm media can be used in the mill. Final products from the mill can be as fine as D100<100nm.

DMQ-series

For information about Union Process Mills that can be used in Lithium Iron Battery applications, please see:

www.unionprocess.com/wet_prod.html *(wet grinding)*
www.unionprocess.com/dry_prod.html *(dry grinding)*
www.unionprocess.com/dmq_mill.html *(small media or bead milling)*

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