BYK

TECHNICAL INFORMATION

ADDITIVES FOR LI-ION BATTERIES

A member of ALTANA

Contents

Introduction

Lithium-ion cells have become an indispensable part of the modern mobile world, from smartphones to electric cars – here, BYK additives are of great importance, as they make the production process more efficient and ensure better product properties. In the manufacturing of Li-ion batteries, for example, the good dispersion of particles is crucial for the performance, as is the control of interfaces and the perfect coating of substrates. Additives BYK supplies to this market are mainly used in the production of electrodes and ceramic-coated separators.

Wetting and dispersing additives from BYK make it easier, for instance, to disperse conductive carbons like carbon black and carbon nanotubes (CNTs). This allows the production of homogeneous electrode slurries for an improved anode and cathode manufacture. The viscosity of these slurries based on lithium iron phosphate (LFP), lithium nickel cobalt manganese oxides (NCM), lithium nickel cobalt aluminum oxide (NCA), or various other active materials can also be reduced significantly. Besides, BYK's wetting and dispersing additives are also applicable for the dispersion of ceramic materials like alumina and boehmite in separator coatings.

Surface additives, in turn, optimize substrate wetting and leveling by reducing surface tension, thus ensuring a fast and defect-free coating of separators. The BYK additive portfolio is rounded off by tailor-made defoamers, rheology additives for adjusting flow behavior, and binders for enhancing adhesion strength, flexibility, and heat resistance.

For additional information on additives and technical topics, please contact us:
battery.byk@altana.com

Note

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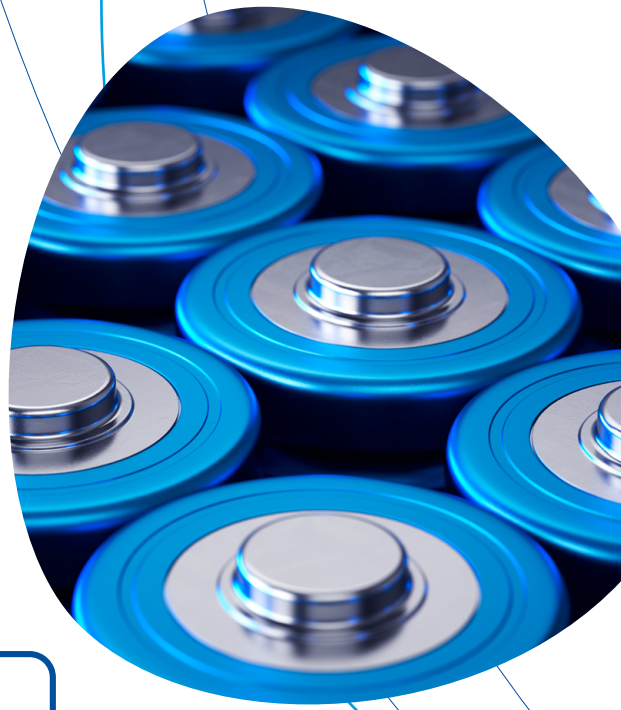
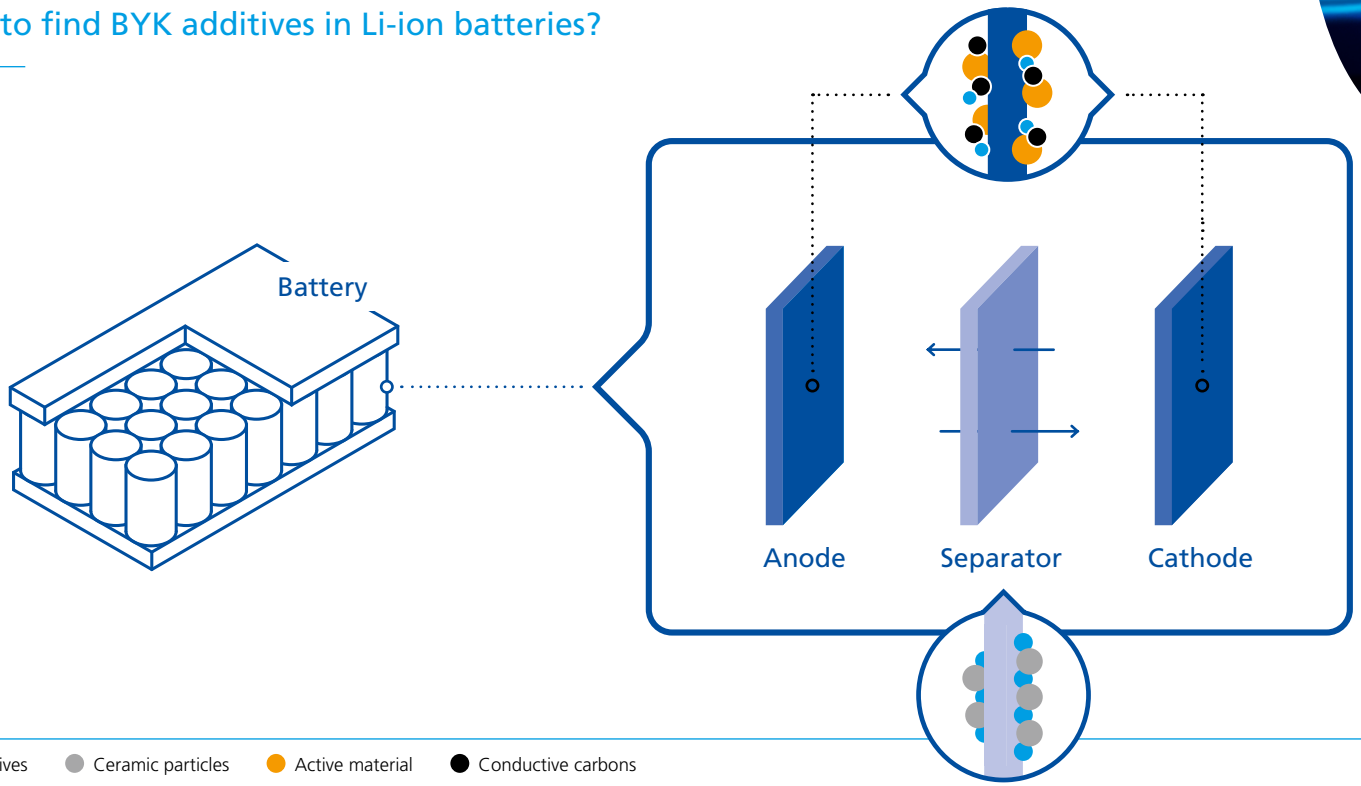
BYK additives for high-quality lithium-ion cells



BYK offers additives from the BYK-ET range designed for application in electrodes and ceramic-coated separators of Li-ion cells. Although the additives are only added in small quantities, they strongly contribute to improving the manufacturing process and product properties as well as the safety of the cells. The tailor-made additives can be used both in different parts of the batteries and different steps of the production process. In conductive pastes or electrode slurries, BYK additives enhance the dispersion and stabilization of conductive carbons or active materials providing a more homogeneous electrode coating. Consequently, they improve the adhesion strength and the flexibility of the coating. The defect-free coating of separators is crucial for the safety of Li-ion cells and can be achieved by using a versatile range of additives, like wetting and dispersing additives to stabilize ceramic particles, defoamers for "defect-free" surfaces, and further additives to improve the wetting of hydrophobic surfaces or to increase adhesion strength.

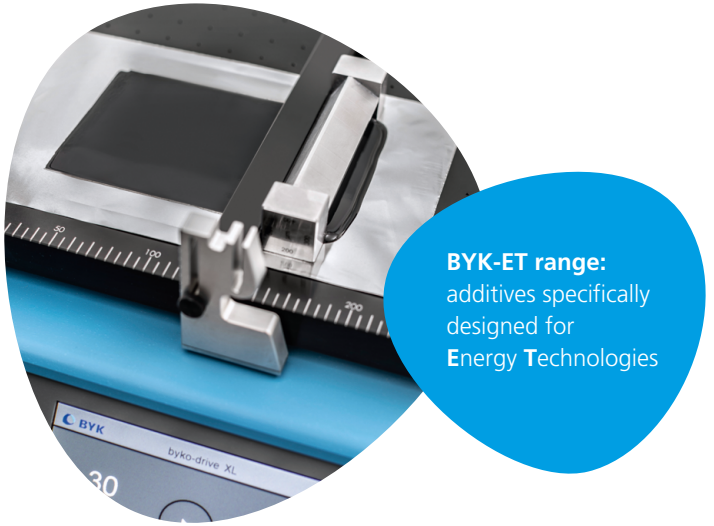
Where to find BYK additives in Li-ion batteries?



BYK additives · Ceramic particles · Active material · Conductive carbons

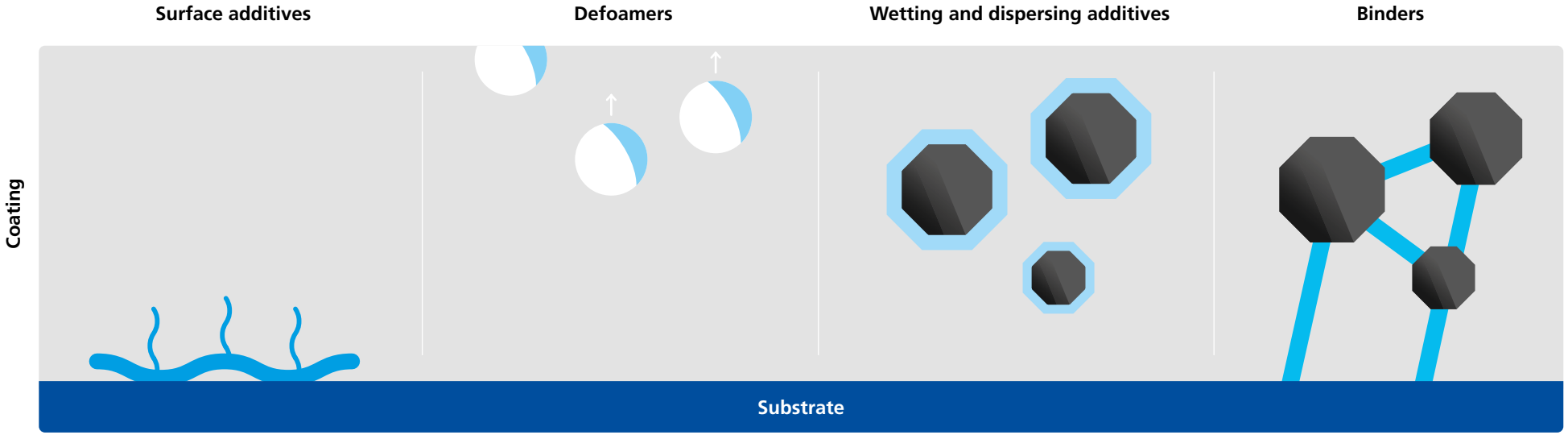
G.01

BYK supplies additives that work at the interfaces in electrodes and separator coatings to improve the production process and properties of the coating. As shown in G. 02, surface additives work at the coating-substrate interface, defoamers at the air-dispersion medium interface, wetting and dispersing additives at the particle-dispersion medium interface, and binders between particles and at the coating-substrate interface.



BYK-ET range:
additives specifically designed for
Energy **T**echnologies

BYK's product groups for battery applications

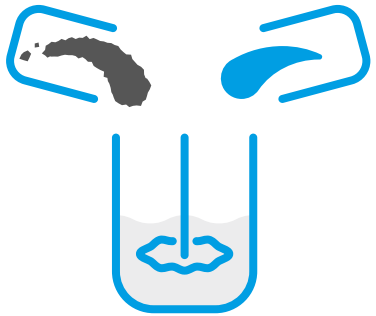


G. 02

Electrodes

The manufacturing process

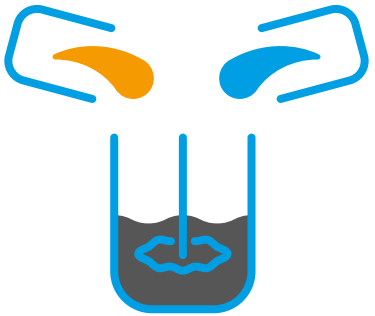
1. Conductive paste preparation



Conductive carbons like carbon nanotubes (CNTs), carbon blacks, and others are dispersed in the solvent together with wetting and dispersing additives for a homogeneous dispersion and an optimal stabilization of the conductive paste.

Benefits:
- Shorter grinding and dispersion time
- Homogeneous particle distribution
- Stable paste
- Energy savings

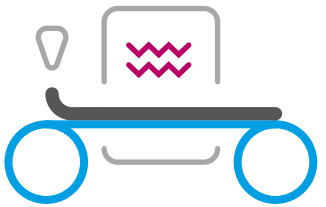
2. Electrode slurry preparation



The conductive paste is supplemented by active material such as NMC or LFP, further wetting and dispersing additives for the dispersion of metal oxides and binders. Rheology additives and adhesion promoters additionally improve the adhesion strength and mechanical resistance of the slurry.

Benefits:
- Viscosity reduction
- Higher solid content
- Less solvent
- Anti-settling
- Faster processing
- Increased efficiency of existing equipment

3. Coating and drying



The electrode slurry is applied to the current collector by various coating and drying processes. The results are improved by the additives used in the manufacturing process prior to the coating.

Benefits:
- Thicker coating
- Shorter drying time due to higher solid content
- Homogeneous coating
- Anti-cracking
- Improved leveling
- Energy savings in the drying process

Additives for electrode slurries

Wetting and dispersing additives
The dispersion of particles like conductive carbons is of great importance within electrode slurry manufacturing. The use of BYK's wetting and dispersing additives allows the preparation of fine and homogeneous distributed carbon pastes and ensures the long-term stability of the slurry, as they stabilize dispersed particles from re-agglomeration.

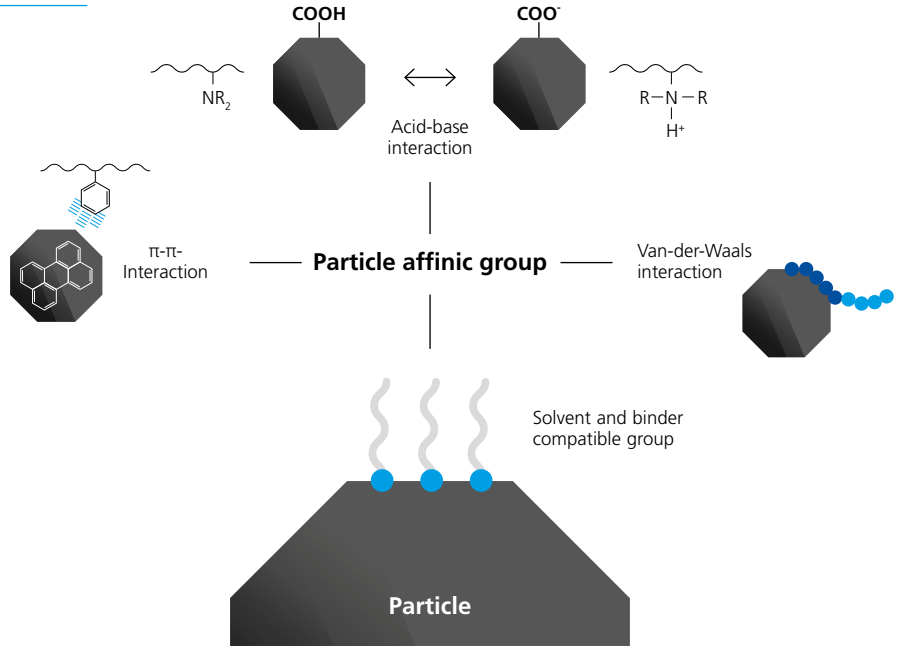
These effects are based on the additive's polymeric structure, which combines two functionalities.

The surface-affinic functional groups adsorb on the particle surface, whereas the solvent- or water-affinic parts interact with the solvent and binder. This results in an improved wetting of the particles and prevention of re-agglomeration by electrostatic repulsion and/or steric hindrance (G. 04).

The homogenous particle distribution is visible in microscope images of a CNT dispersion prepared without and with additive. The sample with wetting and dispersing additive already reaches the targeted CNT particle size, whilst the sample without additive still shows CNT agglomerates resulting in poor conductivity (G. 05).

Benefits:
- Better storage stability
- Higher solid content possible, leading to shorter drying time and improved productivity of electrode manufacturing
- Better particle distribution leads to better conductivity

Polymeric wetting and dispersing additive adsorbed on particle surface and selection of particle-affinic groups

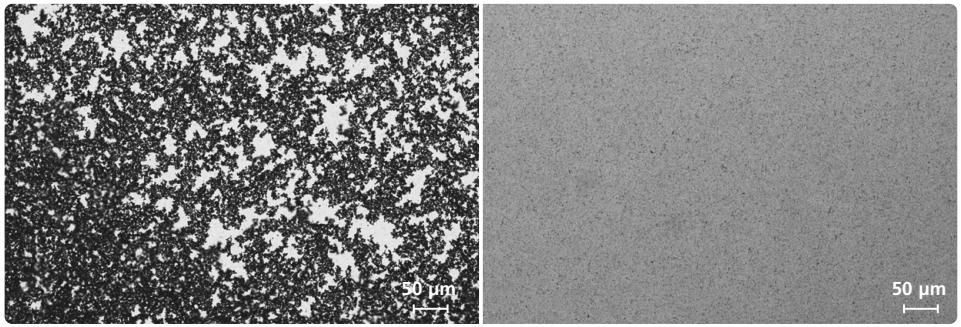


G. 04

Microscope images of a CNT dispersion

Without wetting and dispersing additive

With wetting and dispersing additive



G. 05

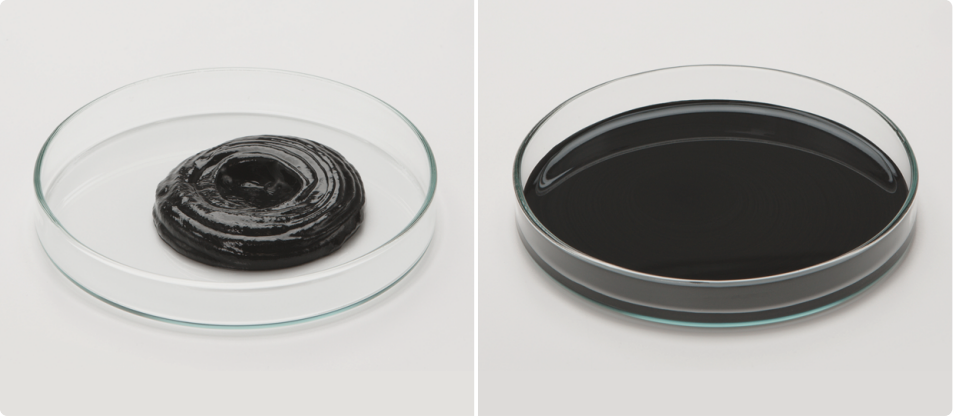
The improved particle dispersion and stabilization additionally results in a significant reduction in viscosity of aqueous and solvent-borne slurries. Therefore, higher solid contents are accessible, which accelerates the drying process and improves the productivity of the electrode manufacturing. As an example, G. 06 depicts a conductive carbon dispersion without and with additive. The sample without is a sticky paste, whereas the sample including BYK-ET products is a low viscous fluid, which shows excellent storage stability.

Shorter grinding times and less solvent in the system decrease energy consumption and production costs (G. 07).

Viscosity reduction of a conductive carbon paste using wetting and dispersing additives

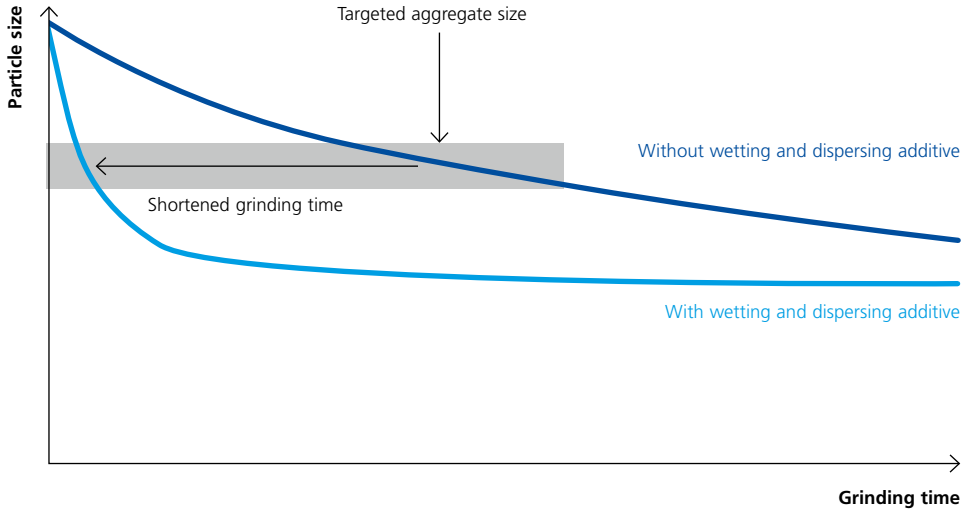
Without wetting and dispersing additive

With wetting and dispersing additive



G. 06

Scheme representing the influence of wetting and dispersing additives on grinding time



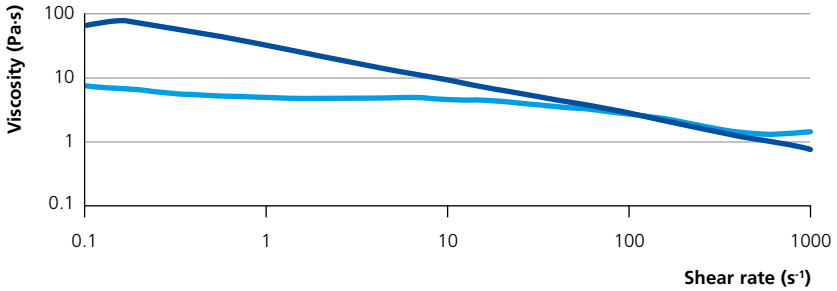
G. 07

Rheology additives
Rheology additives adjust flow properties and improve anti-settling characteristics of the electrode slurries resulting in improved adhesion strength of electrode coatings, better mechanical strength, and an enhanced overall battery performance.

When, for example, the synthetic phyllosilicate LAPONITE-RD is used in combination with polymer thickeners, it develops electrostatic associations with oppositely charged sections on the molecules of polymer co-thickeners, such as carboxymethylcellulose (CMC) and styrene butadiene rubber (SBR). This additional bonding mechanism results in synergistic effects, which enable the formulation of aqueous electrode slurries with high stability (G. 08).

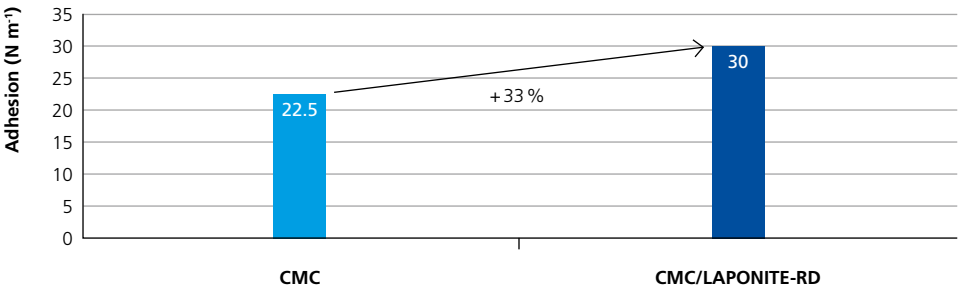
Benefits:
- Improved anti-settling of electrode slurries
- Improved adhesion strength of electrode coatings
- Synergistic effects when used together with polymer thickeners
- Improved slurry stability

Synergistic effect with CMC results in high storage stability



CMC CMC/LAPONITE-RD **G. 08**

Synergistic effect with CMC results in improved adhesion strengh in anodes

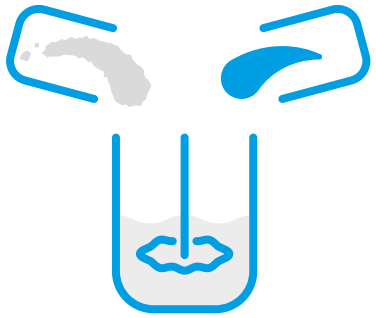


G. 09

Separator coatings

The manufacturing process

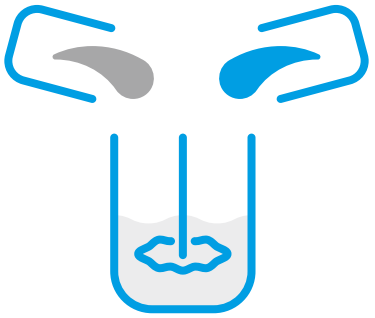
1. Filler paste preparation



Ceramic material, such as alumina, boehmite, or other functional materials such as PVDF is mixed with filler and solvent. Then, wetting and dispersing additives are added.

Benefits:
- Shorter dispersion time
- Homogeneous particle distribution
- Energy savings

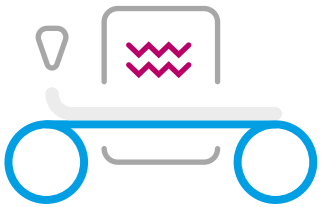
2. Separator coating slurry preparation



The coating slurry is supplemented with surface additives, defoamers, and filler paste. Finally, also binders are added.

Benefits:
- Reduced viscosity
- Higher solid content
- Anti-settling
- Faster processing

3. Coating and drying



The separator coating slurry is applied to the separator by various coating and drying processes. The results are improved by the additives used in the manufacturing process.

Benefits:
- Good adhesion
- Improved heat resistance
- Homogeneous coating
- Enhanced mechanical strength
- Less moisture

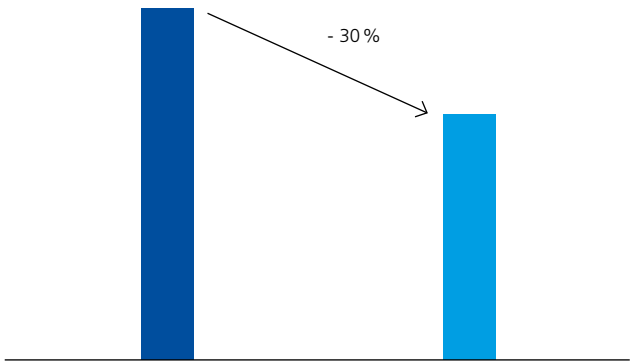
Additives for separator coatings

Wetting and dispersing additives
BYK's polymeric wetting and dispersing additives result in a fine and homogeneous distribution of solid particles in liquid media and ensure the long-term stability of such systems. These effects are based on the additive's polymeric structure, which combines two functionalities. The surface-affinic functional groups adsorb on the particle surface, whereas the solvent- or water-affinic parts interact with the solvent and binder. This results in an improved wetting of the particles and prevention of re-agglomeration by electrostatic repulsion and/or steric hindrance (G. 04). Using a hydrophobic wetting and dispersing additive is also preferable as the moisture uptake of the separator coating is reduced. In some cases, a reduction in moisture uptake of more than 30 % can be achieved (G. 11). BYK offers several types of hydrophobic wetting and dispersing additives to meet a variety of requirements.

PVDF dispersing
PVDF coatings are used to fix electrodes on the separator to improve the battery's safety. BYK offers wetting and dispersing additives that perfectly disperse PVDF particles in water to improve the quality of the coating.

Benefits:
- Improved storage stability
- Reduced water uptake possible
- Better particle distribution

Reduction of water content in separator coatings



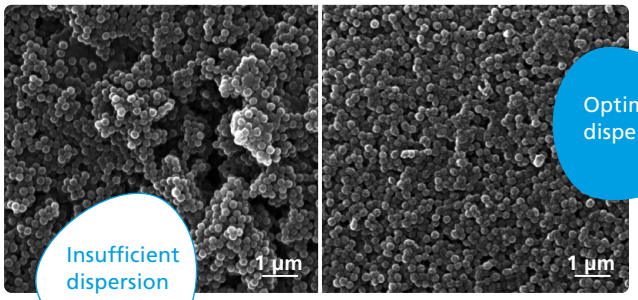
Conventional wetting and dispersing additive
Hydrophobic wetting and dispersing additive

G. 11

Influence of wetting and dispersing additives for PVDF coatings

Without wetting and dispersing additive

With wetting and dispersing additive



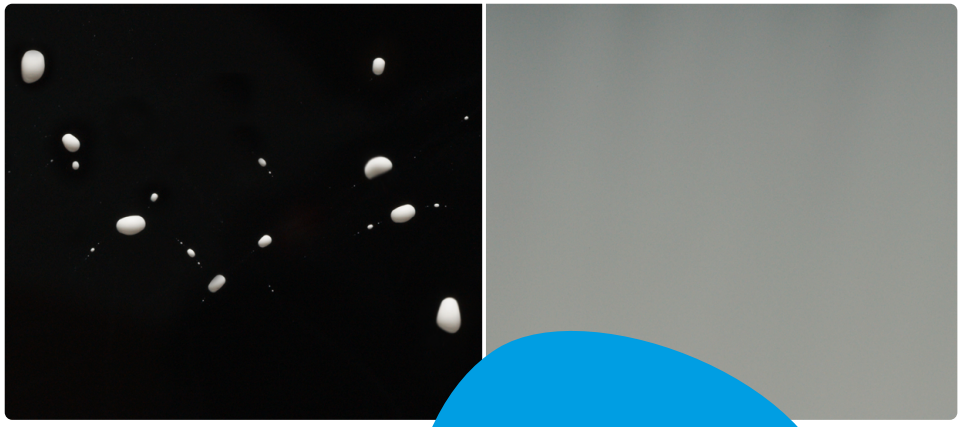
G. 12

Surface additives
These additives can be applied in order to improve the wetting of hydrophobic surfaces with aqueous ceramic slurries, the leveling of the thin coatings, and to adjust the surface energy of the coating in order to provide good wetting with the electrolyte. By significantly reducing the surface tension, an improvement of the coating speed and adhesion of the coating can be achieved.

Defoamers
The dispersion process of ceramic particles is often accompanied by the formation and stabilization of foam (G. 14). Prior to coating, defoaming of the ceramic dispersion is required to ensure a defect-free coating without pinhole formation due to encapsulated foam bubbles. BYK supplies different types of defoamers (e.g. mineral oil defoamers, silicone defoamers, and silicone-free polymer defoamers) that help to minimize foam formation and improve the defoaming process.

Improved wetting

Without surface additive **With surface additive**



For better visualization, the coating was applied to a black substrate.

Benefits:
- Improved substrate wetting
- Improved leveling
- Reduction of surface tension, leading to higher coating speed and better adhesion of the coating

G. 13

Defoaming of ceramic slurries

Without defoamer **With defoamer**

Benefits:
- Prevention of pinholes and other defects in the coating

G. 14

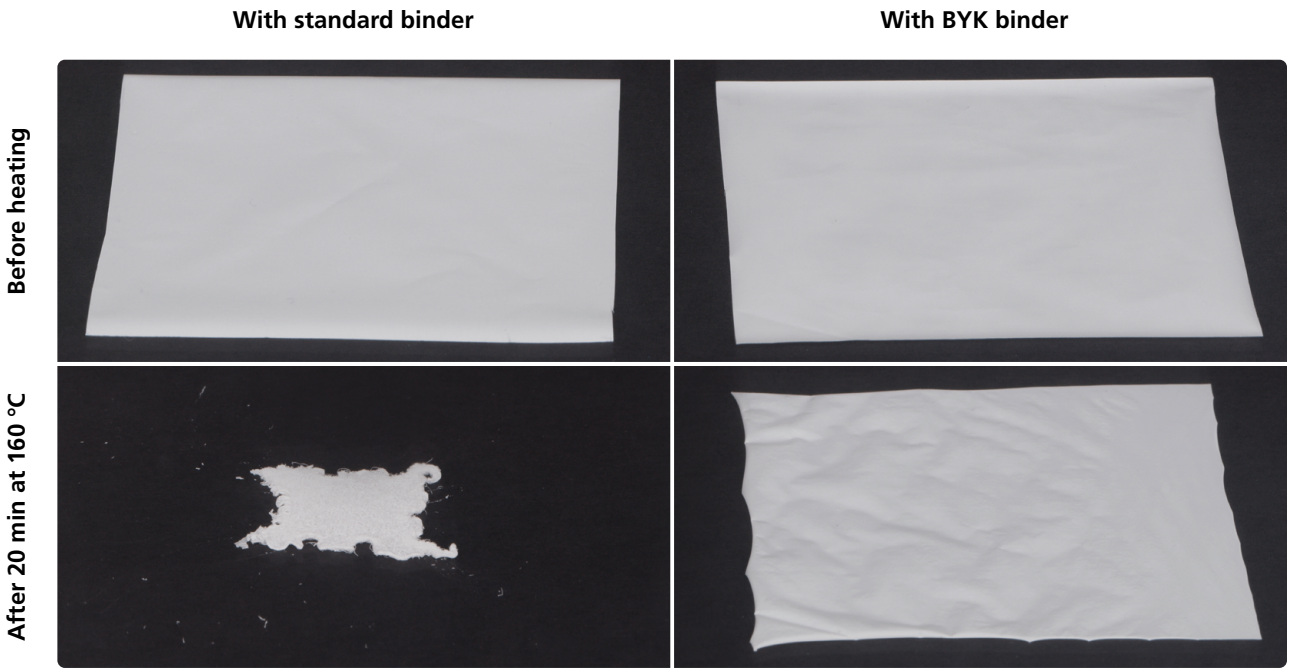
Binders

Binders can fix the ceramic particles onto separators and increase adhesion strength and mechanical flexibility of separator coatings. BYK offers aqueous binders with excellent heat stability for usage in battery applications. BYK's binders maintain the separator's air permeability and prevent moisture uptake. Additionally, the wettability of coated separators with electrolytes is kept at a high level.

Benefits:

- Excellent heat stability
- Increased adhesion strength
- Better mechanical flexibility
- No negative impact on air permeability or wettability of the coated separators
- Prevention of moisture uptake

Improved heat stability with BYK binder



G. 15

BYK worldwide

BYK is a leading global supplier of specialty chemicals. The company's innovative additives and differentiated solutions optimize product and material properties as well as production and application processes. The focus of our activities of our Energy Technologies portfolio (BYK-ET) lies in the Li-ion batteries industry.

With our electrochemical laboratory in Amagasaki, Japan, we are able to test and analyze electrode slurry formulations, test formulations for customers, and produce our own battery cells to determine the influence of each additive within the battery cells. With production sites in Asia, Europe and North America, BYK is able to provide support on a global level.

BYK by numbers

About
1,000
samples a day

More than
2,400
employees around the world

40
markets

Investment in R&D
3 times higher than the industry average

More than
35
laboratories
across the globe

Almost
150
years of **expertise**

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BYK-Chemie GmbH
Abelstraße 45
46483 Wesel
Germany
Tel +49 281 670-0
Fax +49 281 65735

info@byk.com
www.byk.com