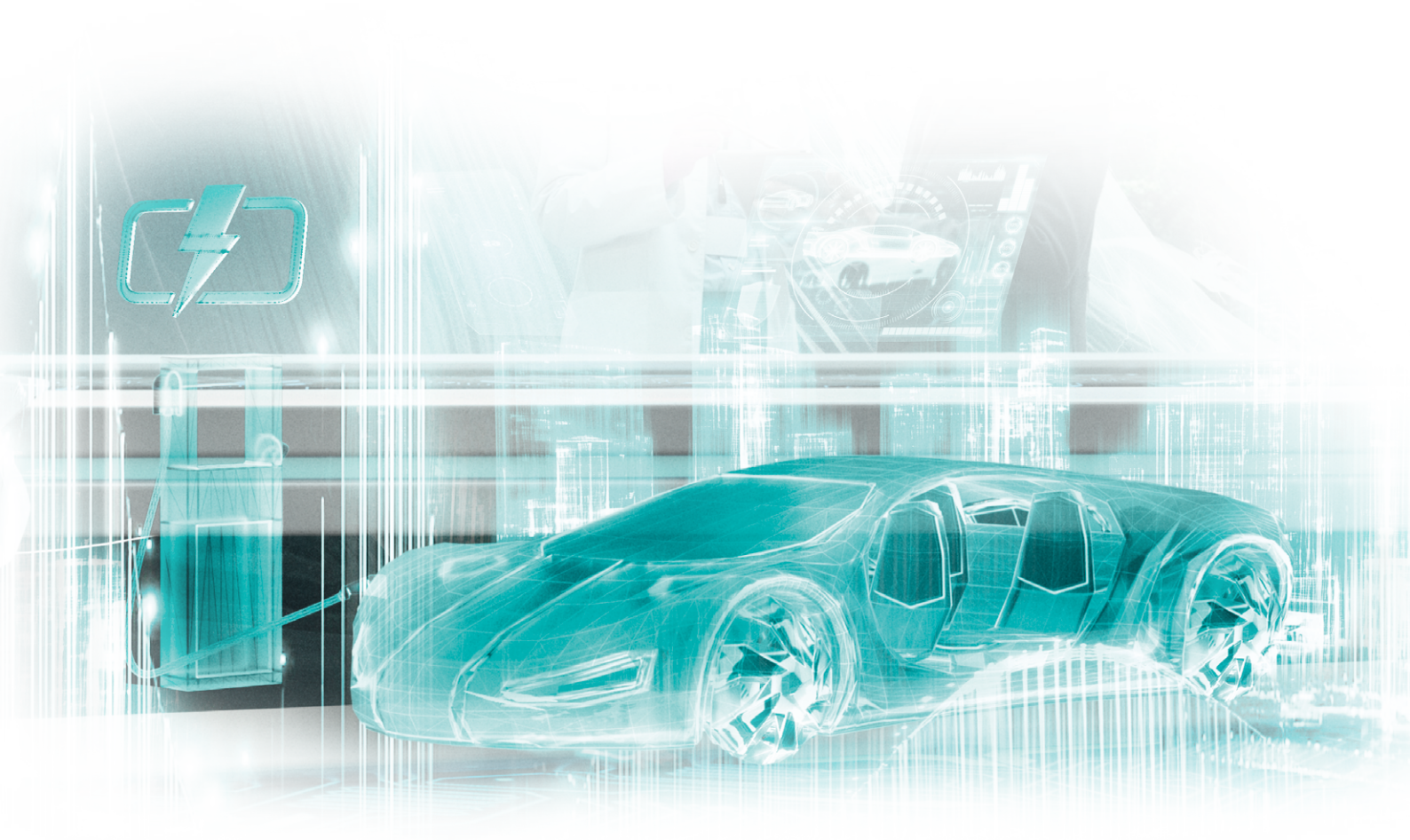
EVONIK SOLUTIONS FOR BATTERY ELECTRIC VEHICLES

**INNOVATE MOBILITY –
WE PROVIDE THE CHEMISTRY.**



EVONIK
Leading Beyond Chemistry


WE GO BEYOND
FOR ENERGY TRANSITION

LEADING BEYOND CHEMISTRY TO IMPROVE LIFE, TODAY AND TOMORROW

Evonik is one of the world leaders in specialty chemicals. The company is active in more than 100 countries around the world. Evonik goes far beyond chemistry to create innovative, profitable and sustainable solutions for customers. More than 32,000 employees work together for a common purpose: **We want to improve life, day by day.**

NEXTGEN

Evonik is embarking on the next phase of its strategic transformation.

The electric vehicle market has seen significant growth around the world, helping to further achieve carbon neutrality goals for a greener future. The shift from traditional petrol-powered combustion engines to hybrid and full EVs has placed lithium-ion batteries at the heart of modern e-mobility solutions.

Evonik's product portfolio for electric vehicle batteries includes a wide range of chemistries and high-performance materials. With raw materials, additives, process enablers and ready to use products, our products improve the performance of our customers' offerings across the entire electric vehicle battery value chain, anywhere it is needed: battery packs, battery cells and battery management systems and battery recycling. And with our next generation solutions, we make the electric vehicle batteries safer and long-living.

Learn more about how we support to boost EV batteries and our chemistry solutions for automotives, please visit:
https://automotive.evonik.com/en

EVONIK GLOBAL LITHIUM-ION BATTERY CENTER (LIB-C)

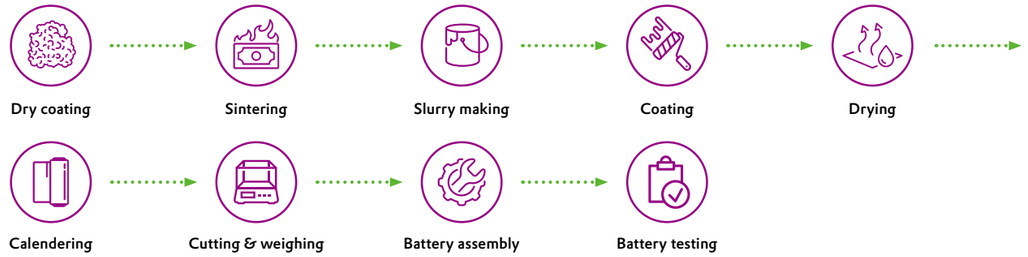
Enhancing service and developing tailor-made solutions for the fast-developing EV battery industry

The Lithium-ion Battery Center (LIB-C) in Shanghai is Evonik's forefront of innovation in the EV battery industry, contributing significantly to the development of high-performance, safe, and sustainable battery solutions. By harnessing cutting-edge technology and fostering collaboration, the center is well-positioned to meet the evolving needs of the electric vehicle market and support the transition to cleaner transportation.

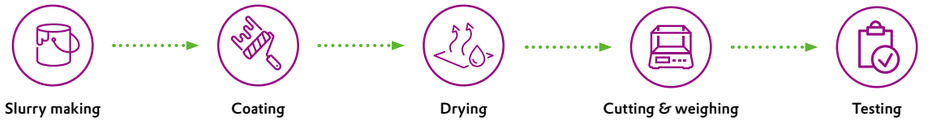
The competence center offers comprehensive support from the initial raw material stage to the production of a ready-to-use battery. Each process step is backed by robust analytics and incorporates next-generation technologies, delivering innovative materials and solutions.

Our state-of-the-art facilities can conduct experiment of key steps for the battery making process

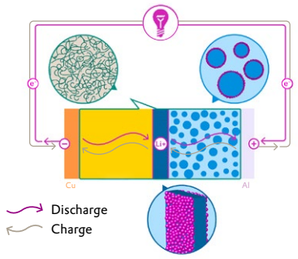
Electrode active material coating and cell testing



Separator coating



EVONIK MAKES THE ELECTRIC VEHICLE BATTERIES
SAFER AND LONG-LIVING



BATTERY CELL

Anode
- AEROXIDE® as dry coating additive on anode active materials improves performance and life-time of Li-ion battery cells.
- TEGO® Surten E series dispersant.

Cathode
- Cathode active materials dry coated with AEROXIDE® improve performance and life-time of Li-ion battery cells.
- TEGO® Surten E series dispersant and flexing agent.
- P84® solution binder and dispersant.

Polymeric solutions for electrolytes
- Gel polymer electrolyte immobilized by functional AEROXIDE®.
- Specialty Methacrylates DP-EM building blocks for enhanced charging speed and overall performance.

Separator
- Microporous membrane coated with AEROXIDE® to improve safety of Li-ion battery cells.
- TEGO® Surten E series wetting and dispersing agent.

BATTERY PACK

AEROSIL® fumed oxides
Provide excellent rheological and reinforcement properties in EV battery structural adhesives.

ALBIFLEX®
Flexibilizer for epoxy resins. Provides toughness, flexibility, and reduces crack formation and polymer degradation caused by thermo-oxidative stress.

ANCAMIDE® and ANCAMINE®
2K epoxy curing agent
Provide excellent adhesive and mechanical property in EV battery structural adhesives and thermal conductive adhesives.

Dynasylan® organofunctional silanes
Provide excellent adhesion and crosslinking properties in structural adhesives and thermal conductive materials.

DABCO® and KOSMOS® series
Amine and metal catalyst help to optimize material properties and curing behavior.

NOURYBOND®
Adhesion promoter of PVC plastisol for EV battery underbody coating, especially for low temperature or short time baking condition.

ORTEGOL® Series
Dispersants and adhesion promotors for PU thermal conductive adhesive and others.

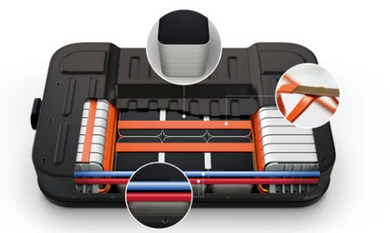
POLYVEST®
Liquid rubber used as highly reactive crosslinking binders or additives for 2K PU for gap filler or thermal conductive adhesive for EV-battery assembling.

TEGO® Therm
Thermal insulation granules and heat-stable silicone hybrid binder for fire-resistant coatings for EV battery housings & covers.

TEGOSTAB® and POLYCAT® SA Series
Silicone surfactants define cell structure and regulate air permeability in foam pads, while delayed-action catalyst help optimize processing windows and enhances flow characteristics.

VESTOPLAST®
APAO for hotmelt adhesive for cell structure bonding, welding point protection and electrode tab bonding etc.

VESTALITE® S curing agent
Allows using optimized epoxy SMC technology for structural lightweight applications.



BATTERY MANAGEMENT SYSTEM

AEROSIL® fumed oxides
Provide excellent rheological and reinforcement properties in EV battery structural adhesives.

AEROXIDE® fumed metal oxide
Functional additives for silicones, adhesives & sealants, and stable thermal conductivity for EV battery pack assembly.

ALBIFLEX®
Flexibilizer for epoxy resins. Provides toughness, flexibility, and reduces crack formation and polymer degradation caused by thermo-oxidative stress.

Dynasylan® organofunctional silanes
Provide excellent adhesion and crosslinking properties in structural adhesives and thermal conductive materials.

Polymer ST and TEGOPAC®
Silane modified polymers and reactive diluents for sealants, gap filler and potting applications.

Polymer VS
Silicone raw materials for thermal management for sealants, gap filler and potting applications.

VESTAMID® PA12
The UL94 flame retardant polymer provides excellent high-voltage insulation properties for power busbar applications according to future safety requirements in EV.

VESTAMID® PA12 tubing systems
Contribute to an ideal thermal management of HV battery, e-motor, inverter and a well-tempered overall ambience of the car.

VISCOBASE®
Dielectric thermal management fluids for improved battery lifetime, thermal efficiency and safe operation.

EVONIK PROVIDES VARIOUS SOLUTIONS FOR **ELECTRIC VEHICLE BATTERY INDUSTRY**

Area		Products	Applications	Benefits	Page
Battery Cell	**Separator**	Fumed metal oxides (Al_2O_3)	Separator coating / incorporation	Improvement of thermal stability of separator	10-15
		Low foaming, wetting agent	Ceramic slurry	Ceramic slurry surface tension reduction	
		Dispersants	Ceramic and PVDF slurry	Slurry viscosity reduction and stability improvement	
	Electrolyte	Fumed metal oxides (Al_2O_3)	Gel / polymer electrolyte	Realize semi-solid electrolyte for safety improvement	
		Specialty Methacrylates DP-EM	Solid polymer electrolyte	Higher ionic conductivity allows for faster charging	
	Cathode	Fumed metal oxides (Al_2O_3, TiO_2)	Cathode Active Material (CAM) coating / doping	Protection of CAMs to enhance capacity retention / battery life	
		Dispersant	Cathode slurry	Slurry viscosity reduction and stability improvement	
		Flexing agent	Cathode	Increasing cathode electrode layer flexibility	
	Anode	Fumed metal oxides (Al_2O_3)	Anode active material (AAM) coating	Protection of AAMs to enhance capacity retention / battery life	
		Dispersant	Anode slurry	Slurry viscosity reduction and stability improvement	
	Cathode / Separator	P84 PI as binder additive	Cathode additive / separator thermal stability	Increasing cathode adhesion strength / increase separator thermal stability	
Battery Pack	**Battery Box**	Curing agent	Epoxy SMC based battery enclosure	Easy processing, lightweight design and low emissions	16
		Epoxy curing agent	Epoxy 2k curing agent	Low viscosity, excellent adhesion and flexibility, fast curing speed	17
		Adhesion promoter	PVC plastisol adhesion	Improving adhesion and baking under low temperature or short time, low odor, phthalates and arene free	
		Polyurethane catalysts	PU adhesives & sealants & foam	Help to tailor reaction profile for desired open-time and fast post-curing	18
		Polyurethane surfactants	PU potting adhesive & froth foam	Optimize cell structure and foam stability	19
		Polyurethane dispersants and adhesion promotors	PU adhesive and sealants	Optimize material properties	

Area		Products	Applications	Benefits	Page
Battery Pack	**Battery Box**	APAO	Hotmelt adhesive for cell structure bonding, welding point protection, electrode tab bonding etc	Excellent electrolyte resistance, high thermal stability, excellent adhesion and hot tack properties, good hydrolytic and UV stability, bonding to various substrates especially on PP without pretreatment	20
		Liquid rubber	2K PU for gap filler or thermal conductive adhesive for EV-battery assembling	Low viscosity, adjusted thixotropy, excellent chemical resistance to acids and bases, high water resistance, low moisture and oxygen permeability, good flexibility	
		Granules and heat stable binder	Fire-resistant and thermal insulation coatings	Coatings with excellent insulation and fire-resistant properties	21
		Silane adhesion promoter	EP, PU, SMP and other adhesives and sealants	Excellent adhesion and curing properties	22
		Fumed silica	EP, PU, SMP and other adhesive technologies	Excellent rheological and reinforcement properties (on page 23)	
Battery Management System	**Power Management and Connectivity**	PA12	Power busbars	For perfect electric insulation	24
	Protection and Thermal Management	PA12	Cooling and heating line and connectors	Excellence performance together with production efficiency, lightweight and competitive system cost	25
		Dielectric fluid	Immersive cooling	Efficient cooling performance that enables fast charging	26
		Fumed silica and metal oxides	Silicones, adhesives & sealants for EV LIB pack assembly	Functional additives to improve processibility, increase thermal conductivity and electrical insulation, improve long-term stability, and anti-settling as well rheology and reinforcement	27
		Silane adhesion promoter	EP, PU, SMP and other adhesives and sealants	Excellent adhesion and curing properties	
		Silicone and filler treatment portfolio	Gap filler and thermal interface material	High flexibility of silicone formulation, improved thermal performance	28
Battery Recycling		Hydrogen peroxide and persulfates	Recycling of Ni, Co, Mn, Li	Recover rare and precious metals for reuse; H_2O_2 also provides effective and sustainable treatment of wastewater	29
Contact Us					30

AEROXIDE® FUMED METAL OXIDES AS **PERFORMANCE ADDITIVES**

Battery Cell

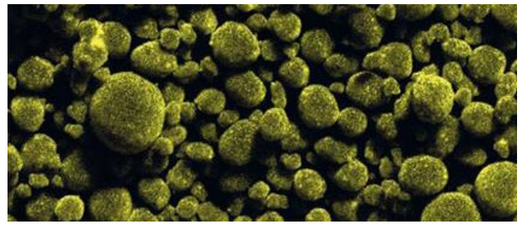
AEROXIDE® fumed metal oxides are produced by flame hydrolysis (AEROSIL® process), the loose white powder consists of nano-structured aggregates. AEROXIDE® metal oxides are used as additives in Li-ion batteries to increase the **performance, life-time** and **safety** of the battery.

Product	Application
AEROXIDE® Alu 130, AEROXIDE® TiO_2 P 25	Protective dry coating for cathode and anode active materials
AEROXIDE® Alu 45, AEROXIDE® Alu C 805 **AERODISP® Ready to use dispersions**	High performance LIB separator as coating or filler
AEROXIDE® Alu C 711	Functional additive in new electrolyte formulations

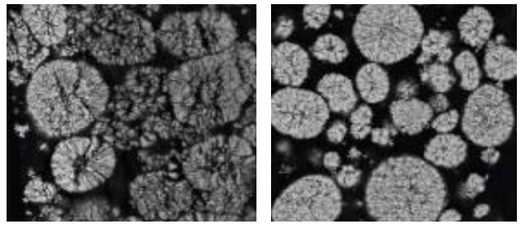
Dry coating for cathode active materials

AEROXIDE® is used for cathode material surface coating to stabilize cathode active material particles and to avoid cracks during charge/discharge, resulting in an increased capacity retention and enhanced battery life.

SEM: Al mapping of AEROXIDE® coated NMC particles

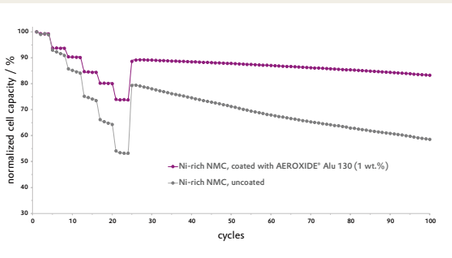


Cross section SEM imaging of cycled electrodes after 250 cycles

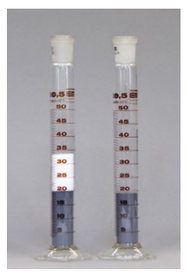


Ni-rich NMC, uncoated

Ni-rich NMC, **AEROXIDE®** coated



Example for stabilization of Ni-rich NMC.



Left
Powder mixture **before** dry coating process:
Uncoated cathode powder
+1 wt.-% AEROXIDE® Alu 130

Right
Final product **after** dry coating process:
1 wt.-% AEROXIDE® Alu 130 coated on cathode powder

AEROXIDE® fumed metal oxides (Al_2O_3 and / or TiO_2) as **dry coating** on cathode particles leads to a significant increase in rate capability and capacity retention of LIB cells.

Preferred AEROXIDE® products:

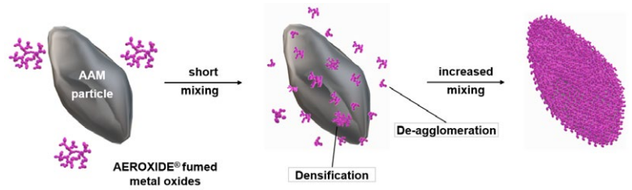
- **AEROXIDE® Alu 130**
- **AEROXIDE® TiO_2 P 25**

} Mixture of both oxides is beneficial

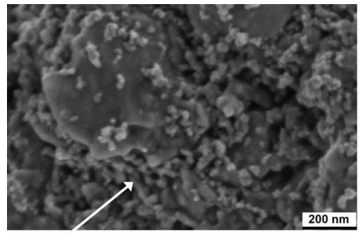
Dry coating for Si-based anode active materials

AEROXIDE® fumed metal oxides as protective coating layer around anode active materials to increase the battery **performance** and **life-time**.

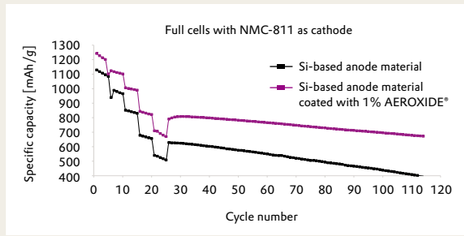
Battery Cell

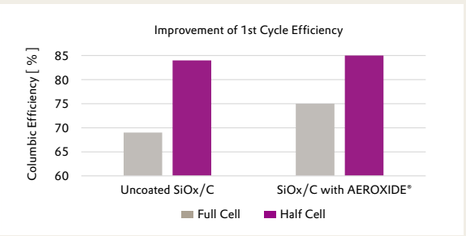


The dry coating process, a solvent-free alternative, uses mechanical forces to attach guest nanoparticles onto micron-sized host particles, relying on van der Waals interactions. The coating improves the interaction with the electrolyte, reducing anode material degradation, i.a. by scavenging of HF and acting as a protective layer on the anode particle surface.



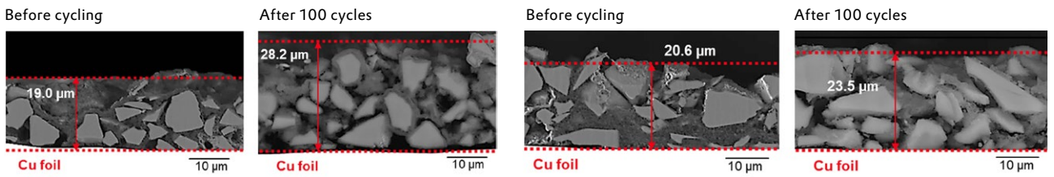
SEM picture of Si-based anode material, coated with 1% AEROXIDE®





The coated anode active materials (AAMs) exhibit improved cycling stability and rate capability compared to the uncoated Si-based material. The dry coating acts as protective layer, reducing unwanted side reactions while simultaneously enhancing Li-ion diffusion kinetics and improving electrolyte accessibility.

The Al_2O_3 coating promotes the formation of a more stable and conductive SEI, rich in LiF, while reducing undesirable components such as LiOH and Li_2CO_3, which are typically associated with increased impedance and capacity fade.



48% volume expansion of uncoated Si-based AAM

14% volume expansion of Al_2O_3 coated Si-based AAM

Post cycling analysis after 100 cycles
Reduced electrode volume expansion and enhanced SEI uniformity

Advantages of anode material dry coating with AEROXIDE®

- The addition of Al_2O_3 to the anode particles creates numerous contact points facilitating bridging between the anode particles, the binder and the Cu current collector to improve cohesive and adhesive strength.
- AEROXIDE® reduces unwanted side reactions with decomposition products from electrolyte during cycle life and is an excellent HF scavenger.
- The enhanced properties of Al_2O_3-coated Si-based anode particles – such as superior cycling stability, rate capability, and Coulombic efficiency – make them highly suitable for use in high-performance LIBs.

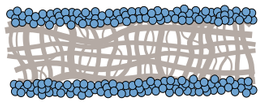
High performance LIB separator as coating or filler

Battery Cell

AEROXIDE® fumed alumina enables the use of ultra-thin (≤ 1 µm), homogeneous ceramic coatings or is applied as ceramic filler inside the membrane, resulting in improvement of thermal stability of separator.

Evonik also offers AERODISP® – Ready to use alumina dispersions, tailor made for specific coating application and compatible with a variety of different binders.

Particle coated

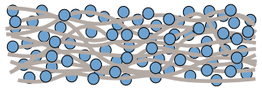


Ceramic particles on top of the microporous membrane

AEROXIDE®

AERODISP®

Particle incorporated

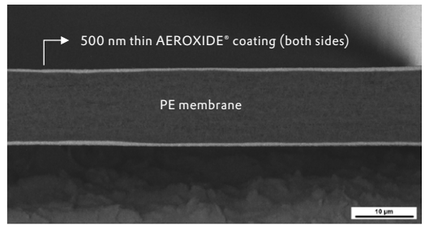


Ceramic particles throughout the whole interior of a polymer matrix

AEROXIDE®

Coating on separator

A thin ceramic coating made of AEROXIDE® fumed alumina protects the separator from thermal shrinkage and thus leads to an increased cell safety.



Cross section SEM imaging of an AEROXIDE® coated PE separator

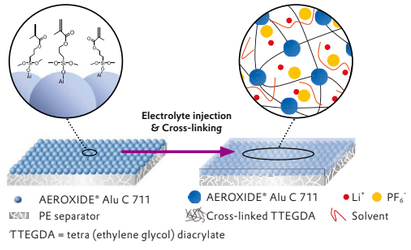
Ceramic filler inside separator

AEROXIDE® fumed alumina can also be used as ceramic filler inside separators, leading to excellent mechanical and thermal membrane properties combined with a high porosity.

Example: Manufacturing of an AEROXIDE® filled separator

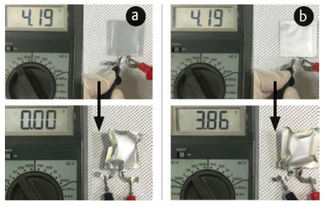
Functional separator coating: Formation of gel polymer electrolyte

AEROXIDE® Alu C 711, a specially designed surface modified fumed alumina, is applied as thin ceramic coating on top of separators, to be triggered a crosslinking reaction with tetra (ethylene glycol) diacrylate (TTEGDA) additive in electrolyte to form electrolyte gelling. The formed gel polymer electrolyte with 3-dimensional network strongly enhances the contact between separator and electrodes.



TTEGDA = tetra (ethylene glycol) diacrylate

Photographs of the opened cell after formation: Composite gel polymer electrolyte is clearly visible



Photographs show the open-circuit voltage of cells assembled with (a) pristine PE separator + liquid electrolyte and (b) AEROXIDE® Alu C 711 coated separator + gel polymer electrolyte, measured before and after thermal exposure at 200 °C for1 h.

Detailed information available: https://doi.org/10.1016/j.jpowsour.2020.228519

VISIOMER® SPECIALTY METHACRYLATES
VERSATILE TOOLBOX OF MONOMERS TO INCREASE BATTERY CHARGING SPEED

Battery Cell

VISIOMER® Specialty Methacrylates serve as effective building blocks in polymeric solutions for Li-ion batteries, enhancing both charging speed and overall performance. Evonik is developing new **DP-EM** with a focus on improving room-temperature ion conductivity.

Product	Application
DP-EM (developmental products)	Amorphous polyether methacrylate monomers to boost ionic conductivity
VISIOMER® PEG 200 DMA	Polyether crosslinker increasing mechanical strength without impeding ionic conductivity

VISIOMER® Specialty Methacrylate monomers for solid-polymer electrolytes in solid-state batteries

VISIOMER® Specialty Methacrylates can be used as building blocks in solid-polymer electrolytes to improve ionic conductivity, particularly at lower temperatures in solid-state batteries. **DP-EM** monomers are proprietary polyether methacrylates designed to prevent crystallization. They serve as the main component of a solvent-free liquid precursor formulation. Thanks to their low viscosity, no additional solvent is required for easy processing. The proportion of **VISIOMER® PEG 200 DMA** in the precursor formulation determines the mechanical properties of the final cured polymer electrolyte, while still ensuring high ionic conductivity.

DP-EM

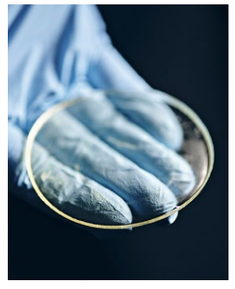
Crosslinker VISIOMER® PEG 200 DMA

(Photo) initiator & Lithium salt

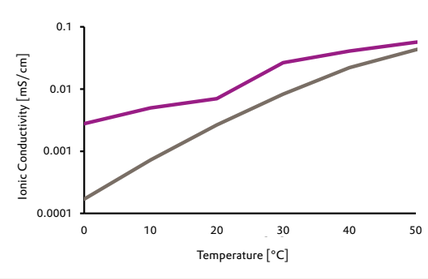
Precursor formulation

Solvent-free liquid formulation

Thermal or radiation curing



Cured solid polymer electrolyte



Ionic conductivity of the VISIOMER®-based electrolytes are superior to the benchmark

Tensile testing of a VISIOMER®-based electrolyte film

Ionic conductivity of the **DP-EM**-based electrolytes is superior to the benchmark.

By varying the concentration of **VISIOMER® PEG 200 DMA**, the mechanical properties of the cured polymer electrolyte films can be tailored to specific application needs.

TEGO® SURTEN E AS PROCESS ENABLER FOR **LIB ELECTRODE AND SEPARATOR MANUFACTURING**

Battery Cell

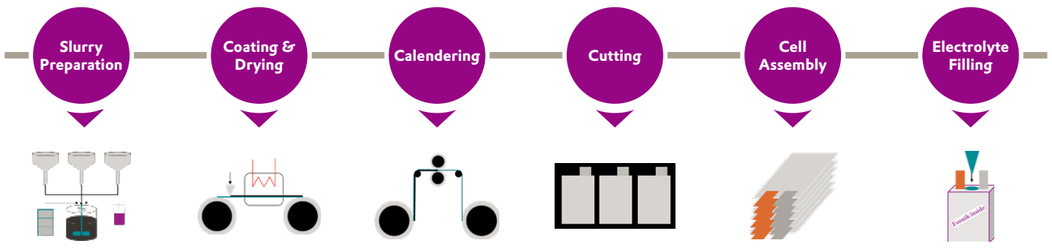
TEGO® Surten E series are the process enablers which help contribute to further improvements in the production of LIB's which yield better electrical performance and lower overall costs. Evonik broad surfactant technology platform allow us to offer a wide range of products from wetting and dispersing agents to defoamers as well as flexing agents.

- NMP based dispersant for cathode
- Water based dispersant for anode, separator
- Evonik provides broad wetting technologies
- Evonik provides all types of antifoam

Product	Application
TEGO® Surten 200 E series low foaming, wetting agent	Separator, surface tension reduction for ceramic slurry
TEGO® Surten 400 E series dispersant	Cathode, conductive paste and separator ceramic slurries, viscosity reduction, grinding time reduction, uniform distribution of active material and conductive materials, long-term stability
TEGO® Surten 800 E series flexing agent	Electrode, improve electrode layer flexibility and reduce electrode layer cracking

Applications and key benefits

Separator coating	Wetting and dispersing agents to ensure uniform coating of ceramics and polymers for maximum production speed while promoting adhesion
LFP Flexing	Dispersants with anticrack properties to improve slurry production and achieve maximum calendaring thickness / compact density for LFP cathodes
CNT Dispersing	Dispersants designed for high aspect ratio conductive carbons, like CNT, to create stable and high-solid containing pastes which improve overall conductivity
Anode Dispersing	Waterborne dispersants that improve the rheologyand distribution of graphite and also conductive carbons in silicon-rich systems
Edge coating	Dispersants designed to improve the ultra-finecoating of ceramics for safety relating edge coating and systems for adhesion promotion in foil primers
Future orientation	Liquid dispersant for next generation solid state electrolyte systems to improve filling speed and ingeneral degassing /defoaming agents



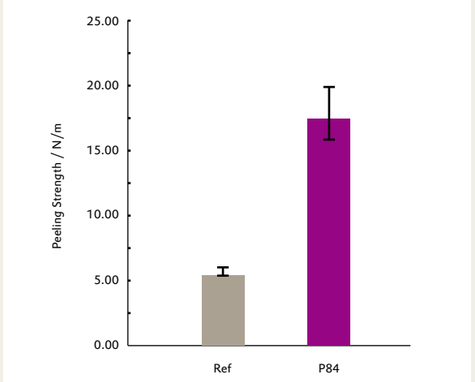
POLYIMIDE P84® AS ELECTRODES **BINDER / DISPERSANT BI-FUNCTIONAL ADDITIVES**

Battery Cell

The effective dispersion of the electrode active materials, and the adhision of the slurry and current collector are very important for the performance of lithium-ion-batteries.

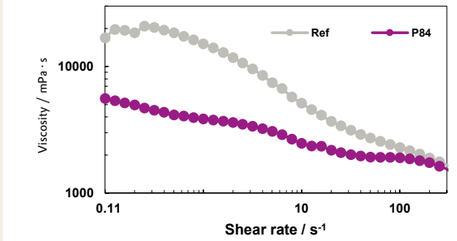
Polyimide P84® can not only disperse the actively materials and conductive materials effectively, but also improve the bonding strength, providing dual effects.

Average peeling strength of electrode with different additives



Sample	Ref-blank	P84
Peeling Strength (N/m)	5.73 ± 0.23	17.81 ± 1.60

The viscosity of LFP slurry with different dispersant



Shear rate (s^{-1})	Ref (mPa · s)	P84 (mPa · s)
0.1	16846	5595.9
1	15115	3845.9
10	5125.4	2465.2
100	2285.8	1899.5

The average peeling strength increase from 5.7 to 17.8 N/m by adding 3 wt% of polyimide P84 solution.

Polyimide P84 solution decreases the viscosity of electrode slurry by 66.8%.

EPOXY SMC BASED BATTERY ENCLOSURE

Battery Pack

VESTALITE® S curing agent is a high performance solution for sheet molding compound (SMC) material with low VOC when combined with a liquid epoxy resin.

Its unique properties make it suitable for automotive applications in large scale automated manufacturing (e.g. battery enclosure).

CONSORTIUM APPROACH

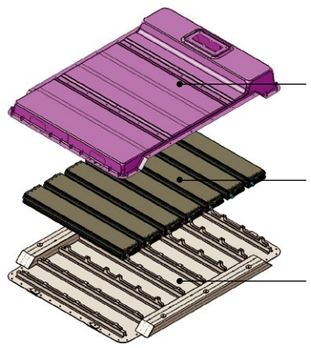
Joint development of Evonik's Joint Venture Vestaro and further partners including Forward Engineering, Lorenz, Lion Smart and Minth.

HARDWARE DEMONSTRATOR

Epoxy SMC based on VESTALITE® S enables easy processing as the material shows excellent mold flow combined with fast curing.

CONCEPT DEVELOPMENT

Multi-Material-Design to address all relevant functions and requirements of an integrated battery system.



More solutions available:
Structural adhesives for Electric & Electronics
Ancamine® cyclo-aliphatic amine and Ancamide® polyamide curing agents offer a wide product range to modify Tg, viscosity, latency, cure speed and toughness of 2K adhesives for ambient and heat cure applications for battery enclosures and structural applications in electric vehicles.

CONCEPT USPs & BENEFITS

Efficient material usage
- Complex geometric shape for part reduction and optimal system packaging
- Multi-material usage to address different requirements like fire resistance or EMC
- Best in class mechanical performance of EP-SMC and local reinforcement materials enables low battery weight

Functional integration
- Integration of module connection parts and further battery system relevant components (e.g. E / E-architecture)
- Integration of sealing and venting elements

Cost effective design and manufacturing
- Modularity of battery system sizes due to specific tooling concept and adjustable "Light Battery" module sizes
- Outstanding energy and power density at low costs

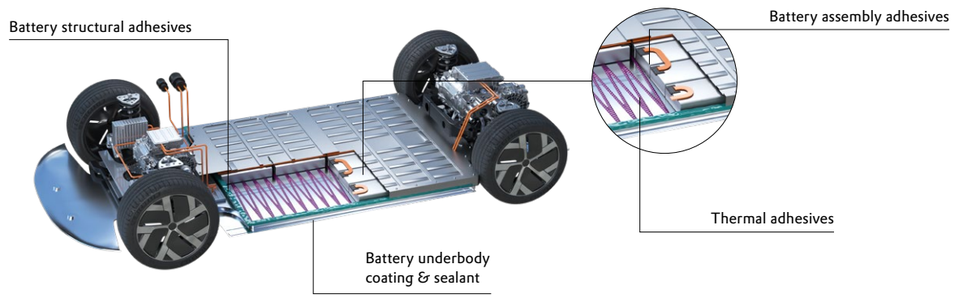
EPOXY CURING AGENT FOR BATTERY ADHESIVES AND SEALANTS

Battery Pack

ANCAMIDE® offers a range of polyamides and adducts to be used in EV battery adhesives with improved adhesion, lower viscosity and faster cure speed.

ANCAMINE® with modified aliphatic and cycloaliphatic curing agents provide various choices in EV battery adhesives, such as pot-life, viscosity, cure speed, and chemical resistance.

NOURYBOND® is the broadest range of high-performance adhesion promoters for automotive PVC and acrylic plastisols in the world. The Nourybond® polyamide-based and blocked isoyanate-based technologies provide solutions to the most demanding performance requirements.



Epoxy 2K curing agent

Product	Viscosity	AHEW	PHR	Gel Time	Features
ANCAMIDE® 910	6,000 mPa.s	230	110-125	120 min	• Outstanding flexibility and peel strength • Excellent thermal shock resistance • Better adhesion to a wide variety of substrates
ANCAMINE® 1922A	10 mPa.s	55	229	57 min	• Produces exceptional toughness, resiliency • Thermal shock resistance and outstanding impact resistance • Good electrical properties
ANCAMINE® 2914UF	300-2,000 mPa.s	95	50	8 min (20 g mix)	• Ultra-fast cure speed at room temperature • Excellent mechanical properties • Can be used as accelerator

Adhesion promoter in PVC plastisol

Product	Viscosity	Amine Value	Features
NOURYBOND® 272	15,000-35,000	185-200	Standard adhesion promoter for PVC plastisols, designed for low-temperature curing at 130 °C within 30 minutes
NOURYBOND® 276	8,000-28,000	110-130	Adhesion promoter for visible PVC plastisols, offering excellent rheological properties and designed for low-temperature curing at 120 °C for 30 minutes

Viscosity:
Brookfield RVTD, Spindle 4, mPa.s at 25 °C

PHR:
With bisphenol-A based epoxy resin (EEW=190)

Gel Time:
Techne GT-3 gel timer, 150 g mix at 25 °C (unless indicated otherwise)

Amine Value:
Perchloric acid titration, mg KOH/g

POLYCAT® SA, KOSMOS® & DABCO® SERIES FOR **THERMAL CONDUCTIVE / STRUCTURAL ADHESIVE**

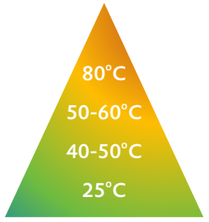
Battery Pack

- Tailor curing profile for optimizing your process and formulation
- Enable a process transfer to automated production
- Improvement of aging stability

Recommended product series

Products	Description
POLYCAT® SA series	• Thermolatent amine catalysts • Suitable for aromatic system • Balancing pot-life and through cure
KOSMOS®, DABCO® series	• Delayed action catalysts • Suitable for aromatic and aliphatic system • Balancing pot-life and through cure

Activation Temperatures of Thermolatent Amine Catalysts



POLYCAT SA 8
POLYCAT SA 102
POLYCAT SA 2 LE
POLYCAT SA 5

ORTEGOL® DA SERIES FOR **THERMAL CONDUCTIVE / STRUCTURAL ADHESIVE**

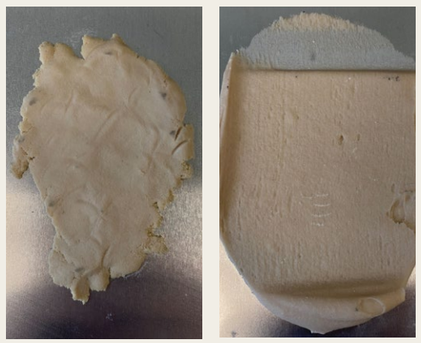
- Reduces viscosity to optimize processing
- Enables higher filler loading helping to maximize thermal conductivity
- Compatible in standard and natural based oils and polyols

Recommended product series

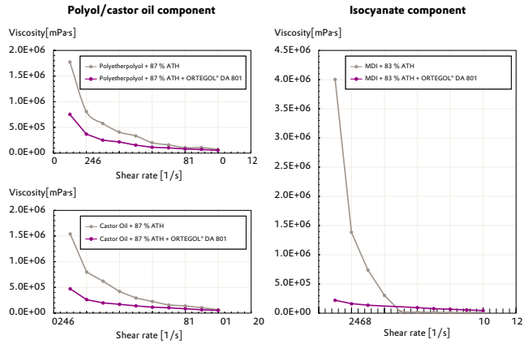
Products	Description
ORTEGOL® DA series	• Suitable for formulations with >80% filler content • Compatible in both, polyol and isocyanate

Conducive to efficient and uniform sizing

No dispersant **ORTEGOL® DA 801**



Efficient performance in reducing viscosity



DABCO®, KOSMOS® & TEGOSTAB® B SERIES FOR **POTTING FOAM**

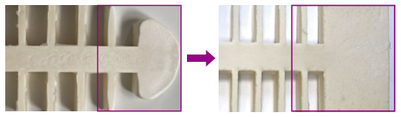
Battery Pack

- Enable optimal flow-ability
- Improving processing with delayed action catalyst
- Improve Adhesion to cells and battery casing

Recommended product series

Product	Types	Description
DABCO® series	Catalyst	Delayed action amine catalyst for improved flow and cure profiles
KOSMOS® series	Catalyst	Hybrid and metal catalyst that provide excellent back end cure performance
TEGOSTAB® B series	Surfactant	Optimize foam stabilization and cell structure
ORTEGOL® AP series	Performance additives	Additive to help improve the adhesion to the metal surface and cells

Efficient flowability to help fill individual slits in complex molds

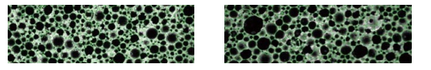


Traditional solution Evonik's solution

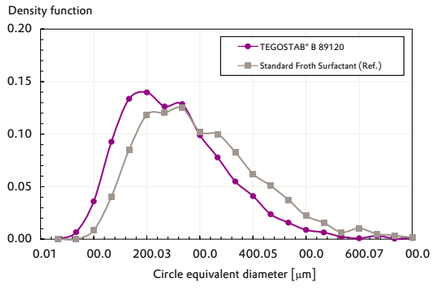
TEGOSTAB® B, KOSMOS® & POLYCAT® SA SERIES FOR **FROTH FOAM**

- Ensure wet froth stability and fine cell retention in drying process
- Low VOC options
- Co-surfactant options for flexibility formulation
- Low toxicity catalyst with ideal processing
- Supports production of low density foams

Evonik solution can help to improve the finesse and uniformity



TEGOSTAB® B 89120 Standard Froth Surfactant



Recommended product series

Product	Types	Description
TEGOSTAB® B series	Surfactant	Silicone surfactants for foam stabilization and cell regulation
KOSMOS® series	Catalyst	Metal catalyst that help provide long open times with a fast cure profile
POLYCAT® SA series	Catalyst	Amine catalyst with thermo-latent behavior to help improve processing latitude and a optimized cure profile

APAO AND LIQUID RUBBER FOR
EV BATTERY ADHESIVES & SEALANTS

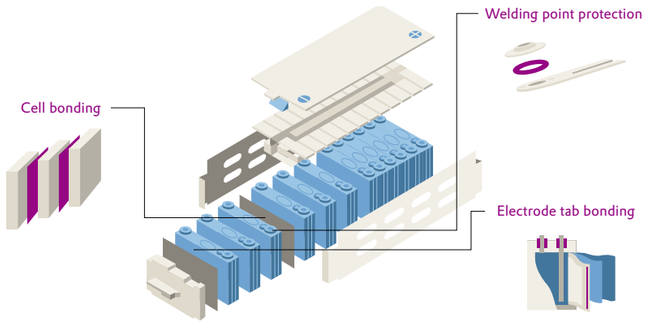
Battery Pack

VESTOPLAST® and POLYVEST® products are widely used as binders/additives for adhesives and sealants in battery cell and pack, enhancing the performance of lithium-ion batteries.

Product	Application
VESTOPLAST® series	Raw material with superior electrode resistance for hotmelt adhesive for cell structure bonding, welding point protection, electrode tab bonding etc
POLYVEST® HT, POLYVEST® HT LV, POLYVEST® MA series, POLYVEST® MAT, POLYVEST® ST-E 60	2K PU for gap filler or thermal conductive adhesive for EV-battery assembling

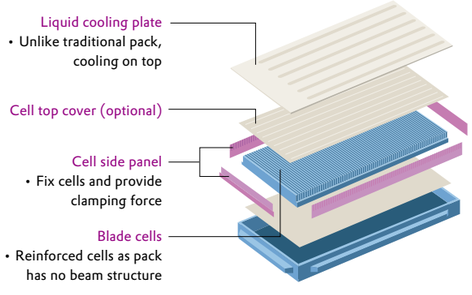
VESTOPLAST® are characterized by the following product properties and show great performance in EV battery system applications.

- Excellent electrolyte resistance
- High thermal stability
- Excellent adhesion and hot tack properties
- Very good hydrolytic and UV stability
- Bonding to various substrates, especially on PP without pretreatment



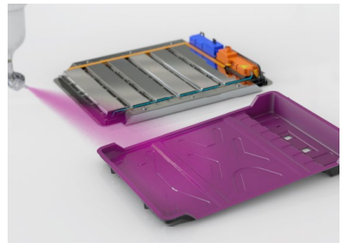
Due to its microstructure POLYVEST® grades are highly reactive crosslinking binders or used as additives providing properties including:

- Low viscosity
- Adjusted thixotropy
- Excellent chemical resistance to acids and bases
- High water resistance
- Low moisture and oxygen permeability
- Good flexibility



HEAT PROTECTION AND FIRE-RESISTANT COATINGS
THERMAL INSULATION GRANULES AND HEAT-STABLE SILICONE HYBRID BINDER FOR FIRE-RESISTANT COATINGS FOR EV BATTERY HOUSINGS & COVERS

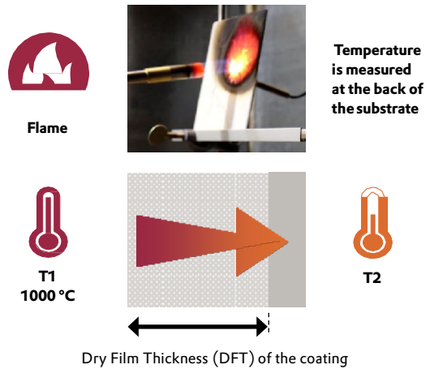
Battery Pack

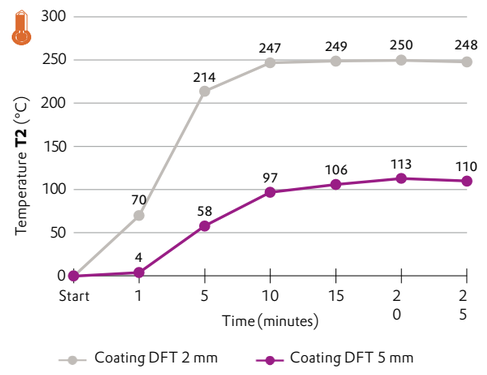


The use of thermal insulation barriers in lithium-ion batteries is to mitigate the risk of fires resulting from infrequent but hazardous thermal runaway incidents in EV batteries. Fire-resistant coatings applied to battery covers represent one approach to reduce the risk of thermal runaway incidents. The TEGO® Therm product line facilitates tailor-made raw materials to formulate sprayable coatings that provide excellent fire resistance and thermal insulation characteristics. The combined use of microporous silica-based TEGO® Therm HPG granules and the heat-stable TEGO® Therm L300 binder allows to formulate flame-retardant coatings that meet the UL 94 V-0 fire safety standards.

Coatings formulated with TEGO® Therm effectively minimize heat transfer to the underlying substrate while preserving superior mechanical integrity during direct jetflame testing.

Fire Resistance Test – 20 minutes exposure to a 1000 °C jetflame





Coatings based on **TEGO® Therm L 300** binder combined with **TEGO® Therm HPG** granules can reach a thermal conductivity (λ value) of less than 40 mW/(m K). Thin coatings with a dry film thickness (DFT) of only a few millimeters, suitable for applications with limited space, enable effective insulation and protection of the substrate. Even with a flame temperature of >1000 °C, the temperature on the backside peaked at <250 °C.

TEGO® Therm portfolio – At a Glance

TEGO® Therm L 300

- Liquid waterborne polysiloxane hybrid binder with solid content ~50%
- Superior heat stability
- Low smoke and odor development

TEGO® Therm HPG 4000

- Granules with superinsulation properties from passivated amorphous SiO_2 core
- High hydrophobicity
- Non-combustible / Non-flammable

TEGO® Therm HPG 6806

- Granules with excellent insulation properties from amorphous SiO_2 core
- Small particle size enable smooth coating surfaces
- Excellent dimensional stability

DYNASYLAN® ORGANOFUNCTIONAL SILANES AS **ADHESION PROMOTERS**

Battery Pack

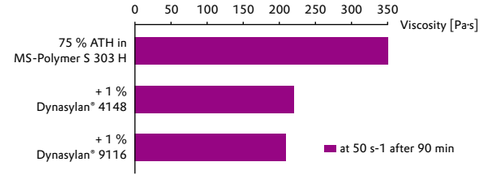
Dynasylan® organofunctional silanes act as adhesion promoters in various EV battery adhesives and sealants. In addition, special Dynasylan® grades can help to adjust the filler loading and rheological properties.

Adhesion promoter in various polymer systems

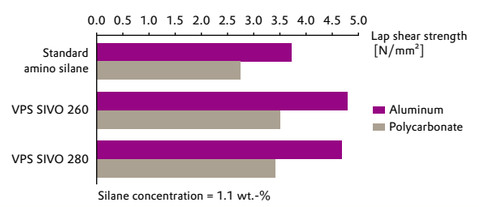
Product	Characteristics	Application
Dynasylan® 1124	Secondary aminosilane	High crosslinking potential for 2K PU, 2K EP, SMP and special primers
Dynasylan® 1146	Oligomeric aminosilane	Suitable for 2K PU, 2K EP, SMP, imparting outstanding hydrophobicity and reduced VOC
VPS® SIVO 260	Oligomeric aminosilane	Excellent adhesion on metal substrates and recommended for 2K PU, 2K EP, SMP
VPS® SIVO 280	Oligomeric aminosilane	
VPS® 4721	Oligomeric epoxysilane	Suitable for PU, EP, and various other polymer systems
VPS® 7163	Isocyanurate silane	High crosslinking potential for PU, EP and other polymer systems
Dynasylan® 9116	Alkyl silane	Capable to adjust the filler loading and rheological properties
Dynasylan® 4148	Polyether silane	

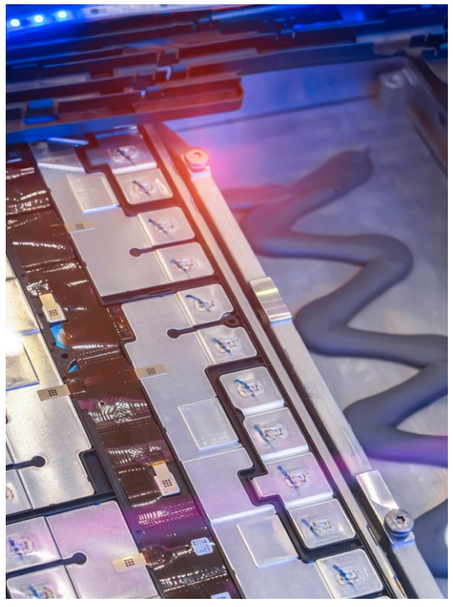
* PU = polyurethane systems, EP = epoxy systems, SMP = silane modified polymer systems

Improve the filler loading and formulations workability by reducing the viscosity at higher shear rates



Enhance the primerless adhesion on aluminum and polycarbonate in STPU systems





Our smart solutions provides a broad range of products including **AEROXIDE®** branded alumina, **AEROSIL®** fumed oxides, **DYNASYLAN®** silanes with tailored properties, increase the performance, lifetime, and safety of Lithium-ion batteries.

INSULATION FOR HIGH VOLTAGE POWER BUSBARS WITH **VESTAMID®** **POLYAMIDE 12**

Battery Management System

Efficient management of electric power and permanently effective insulation of electrical components are key elements in e-mobility. The challenges include management of high voltage, high temperatures, and fire protection.

For more vehicle saftey, a high level of fire protection is expected of the plastics. Basically, the Evonik PA12 insulative materials provide outstanding and constant dielectric properties over the entire vehicle lifetime. This applies to power busbars in the high voltage bordnet, at HV charging and in particular, in high-voltage batteries. Powerbusbars are preferably insulated with polyamide 12 (PA12).

Evonik VESTAMID® PA12 is available at UL fire protection levels and includes halogen-free variants in the portfolio. The PA12 materials are in durable RAL signal color.

Evonik assists customers from setting up parameters for PA12 busbar co-extrusion to the bending of coated busbars and finishing of busbar components. In addition we support with specific polymer testing.

VESTAMID® for xEV power busbars

Properties	VESTAMID® PA12 compounds
Application voltage	High voltage up to 1000 V and more
Busbar metal core	Copper, aluminum, steel, … (also tin / nickel plated)
Coating material	PA12, various grades available, grades UL94 certified
Coating thickness	0.5 – 1 mm
Coating process	Co-extrusion, injection overmould
Color	Orange RAL 2003, RAL 2004, RAL 2008, natural
Flame resistance acc. UL 94 (IEC 60695-11-10)	V0, V2, HB
Halogen-free	Yes
Temperature resistance	Up to +125 °C
Volume resistivity (IEC 62631-3-1)	10^{13} Ωm
Electric strength (acc. to IEC 60243-2, ISO 6722 / 19642)	AC > 25 kV / mm, DC > 40 kV / mm
CTI (IEC 60112)	600

PA12 co-extrusion → **forming and finishing** → **polymer testing**

THERMAL MANAGEMENT WITH TUBING SYSTEMS FROM **VESTAMID®** **POLYAMIDE 12**

Battery Management System

During the high power charging cycles, or while driving (battery discharging), or even while being parked, the temperature of EV battery can exceed the given limit. With lines made from VESTAMID® we provide the suitable solution for both, **water glycol** or **refrigerant** used in the cooling cycles, to enable an effective thermal management and keep the temperature in your car battery at the desired level.

The performance of EV batteries, electric motors, and other high power components benefits from our specialized **mono- and multilayer tubing systems** by keeping its temperatures within the required limits.

For the different performance levels: VESTAMID® offers the right solutions for cooling lines

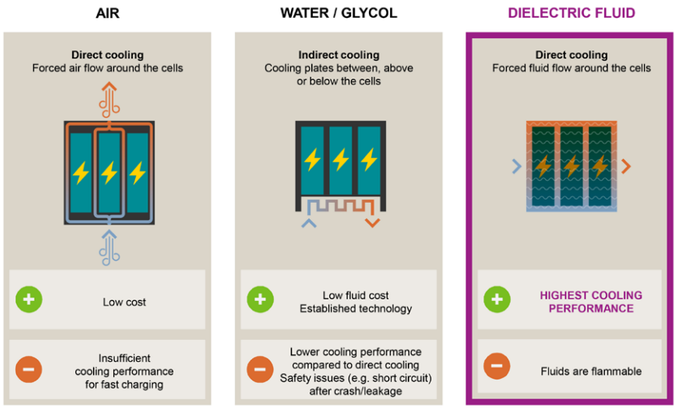
Evonik cooling line solutions based on VESTAMID®

- **High mechanical properties**
  The high mechanical properties of VESTAMID cooling line solutions enable them to replace rubber or metal by saving 30-50% weight. And thanks to the high burst pressure and cold impact resistance at -40°C it saves material, weight and space compared to other polymer solutions.
- **Creep resistance**
  With the high creep resistance even at higher temperatures cooling lines based on VESTAMID are assembled fast and easily with quick connectors for a long lasting and leakage free usage on vehicles. That saves material, storage-keeping and assembling costs for additional wedding ring, cramping or welding.
- **Chemical and stress cracking resistance**
  The VESTAMID cooling line solutions show excellent stress cracking resistance as requested in SAE J2260 § 7.12.1. This ensures the safety of the assembly over the whole lifetime of the vehicle under all environmental conditions. Not self-evident at all for other polymer solutions.
- **Temperature resistance**
  VESTAMID cooling lines as mono layer or multilayer tubing (MLT 8000) can be used over the wide range of temperatures that occurs in cooling loops of vehicles for ICE or for xEV. Specially for BEV, having lower temperature resistance requirements, the MLT 8EV is a high performing solution at budget costs.
- **Sustainability**
  All grades of VESTAMID used for automotive applications are produced with renewable energy and reduce the carbon foot print by 30%, confirmed by Life Cycle Analysis. VESTAMID grades with further reduced carbon footprint like VESTAMID RFP or VESTAMID eCO are available, too.
- **OEM approved globally**
  Monolayer and multi-layer cooling lines with VESTAMID are approved at OEMs all over the globe and since decades in daily usage in millions of vehicles, whether powered by ICE or by battery.

DIELECTRIC THERMAL MANAGEMENT FLUIDS FOR **EV APPLICATIONS**

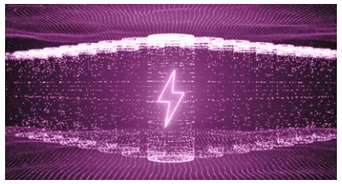
Battery Management System

For the performance, durability and safe operation of a traction battery, it is essential to ensure operation in the optimal temperature range. This requires a powerful thermal management system, which can be achieved with submerging the battery cells in a dielectric fluid. Compared to air or water/glycol cooling systems cooling with dielectric fluids offers numerous design advantages.



Dielectric cooling allows

- Faster charging
- Prolonged battery life
- Electrical efficiency for increased vehicle range



	Unit	VISCOBASE® 11-416	VISCOBASE® 11-151	VISCOBASE® 11-192	VISCOBASE® 11-210	VISCOBASE® 11-262
Kinematic Viscosity at 40°C	cSt	4.1	4.4	5.6	7.9	20.6
Flash Point (ASTM D93)	°C	124	163	189	210	241
Electrical conductivity at 40°C	nS/m	0.0001	0.0001	0.04	0.2	0.0001
Specific heat at 40°C	kJ/kgK	1.92	1.89	1.91	1.81	1.94
Thermal conductivity at 40°C	mW/m*K	123	139	148	148	153
OCP FOM1 at 50°C		60	65	63	58	46

FUMED OXIDES FOR **SILICONES, ADHESIVES & SEALANTS IN EV LIB PACKS**

Battery Management System

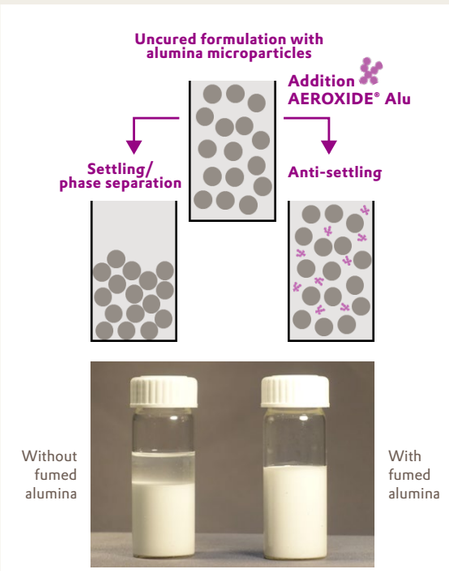
Products	Features	Requirements
AEROSIL® R 202 / R 208 / R 805	Structural adhesives (Battery Pack)	Thickening thixotropy, and reinforcement
AEROXIDE® Alu 65 / Alu 130 / Alu C **Alu 45 / Alu 45 RK** **AEROXIDE® Alu C 805**	Thermal conductivity	Rheology control, anti-settling, homogeneity and stability improvement
AEROXIDE® TiO_2 P 25 / PF2	Thermal stability	Silicone degradation at high temperatures, e.g. in silicone cables, sealants, and gaskets
AEROSIL® 200 / 300 / 380	Thermal insulation	Cost-effective inorganic fillers Highly porous inorganic fillers
AEROSIL® R 104 / R 106 (D4 treated)	Low volatiles	Safe usability on production lines

Additives for thermally conductive formulations

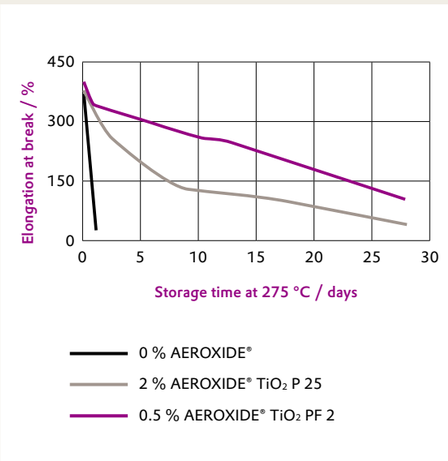
- Anti-settling for micron sized spherical alumina and other thermally conductive fillers
- Lower viscosity for boron nitride filler
- Improved thermal conductivity in addition to the role as rheology modifier and anti-settling agent
- Reducing thickening, featuring with our low surface area fumed alumina e.g. AEROXIDE® Alu 45 / Alu 45 RK

Additives for silicones

- AEROXIDE® TiO_2 PF 2 is a unique fine particle mixed oxide consisting of titania and iron oxide, manufactured analogous to the AEROSIL® process
- Hydrophobized silica such as AEROSIL® R 104 / AEROSIL® R 106 offers a safe production environment due to low content of D4 volatiles



Elongation at break of silicone rubber at high temperature:
adding 1.0 – 3.0 wt.-% of AEROXIDE® TiO_2 P 25 or 0.25 – 1.0 wt.-% of AEROXIDE® TiO_2 PF 2 is an effective solution to improve the thermal stability of silicones



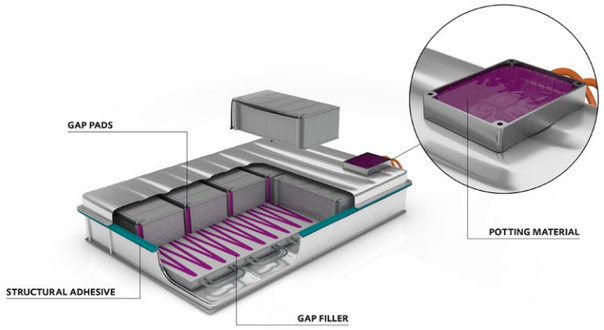
SILICONE AND FILLER TREATMENT PORTFOLIO FOR **BATTERY ASSEMBLY**

Battery Management System

Silcone and other reactive resins

Product	Application
Polymer VS silicones and Crosslinkers	Vinyl-terminated silicone portfolio with broad range viscosity starting from 20 mPas
	Full range with different SiH contents & viscosity
Modifier 700 series	Di-functional SiH structure to archive low process viscosity and high elongation properties
VQM 900 series	Vinyl-functional QM resin for high mechanical properties and transparent formulations
ALBIFLEX®	Si/EP Hybrid Polymer for very flexible, vibration absorbing, highly filled Epoxies
Polymer ST and TEGOPAC®	Silane terminated polyethers as binders and reactive diluents

Our full portfolio of silicone raw materials give high flexibility to build your formulation with desired viscosity, curing speed, hardness and high performance. Guiding formulations and technical exchange with our experts upon request.



Evonik solutions include:
Raw materials and additives for

- Gap fillers
- Thermal interface materials
- Battery assembly adhesives
- Sealants
- Potting and encapsulants

Filler treatment portfolio for better thermal conductivity and flame retardancy

Product	Application
TEGOPREN® 6875 & 6879	Organo-modified siloxane chemistry for hydrophobic treatment of functional filler. Can also be used as in-situ dispersion additive
TEGOMER® DA series	Broad chemical portfolio for filler treatment and in-situ additive in matrix

TEGOPREN® and TEGOMER® products enhance the functionality of different fillers in silicone, urethane, epoxy, acrylic and thermoplastics. Filler treatment benefits include:

- Improved filler distribution in the matrix leading to higher thermal conductivity, better flame retardancy and lighter weight
- Reduced formulation and processing viscosity and lower water uptake
- Further increase of functional filler dosing level which enables even higher performance

We also offer high performance raw materials including NANOPOX®, ALBIFLEX® and ALBIDUR® for the flexibilisation and long-term performance of epoxy.

LIB RECYCLING WITH HYDROGEN PEROXIDE AND PERSULFATE **ECO-FRIENDLY OXIDANTS**

Battery Recycling

Lithium-ion batteries (LiBs) are widely used in electric vehicles and smart portable devices. As more and more of these items reach the end of their life cycles, it is becoming increasingly critical to recycle the LiBs in order to reuse the rare and precious metals contained within them, such as lithium and cobalt. Hydrogen peroxide and persulfate are uniquely positioned to aide in the recovery of these metals during the LiB recycling process.

Product	Application
HYPROX® 350, HYPROX® 500	Recovery of Li, Co, Ni, Mn in the leaching processes
CLAMARIN® 350, CLAMARIN® 500	Wastewater treatment to breakdown organics to reduce COD
Ammonium persulfate and sodium persulfate	Oxidative leaching of oxidizable metals such as lithium

Application overview

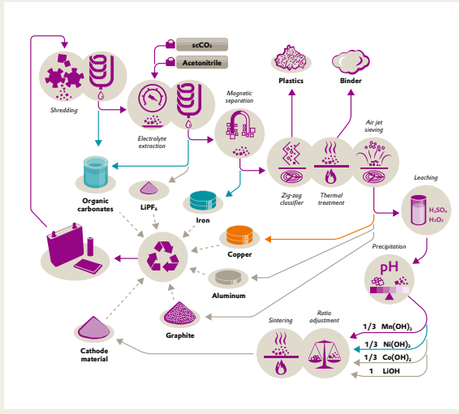
Hydrogen peroxide

Among the various LiB recycling technologies, one widely implemented process is called "wet hydrometallurgy". Here, hydrogen peroxide (H_2O_2) is used as a reduction agent in the leaching step to:

- Oxidize or reduce the metals such as Co, Mn, Ni, Li, and Fe to aide in their recovery from the LiB substrates;
- Increase leaching efficiency and shorten leaching time;
- Because hydrogen peroxide decomposes into only water and oxygen, it leaves minimal trace on the environment.

Hydrogen peroxide is also an effective and sustainable solution for wastewater treatment: It can be used alone or in combination with advanced oxidation process (AOP) technologies to break down organic chains to reduce the chemical oxygen demand of wastewater.

Process flow scheme of wet hydrometallurgy LiB recycling

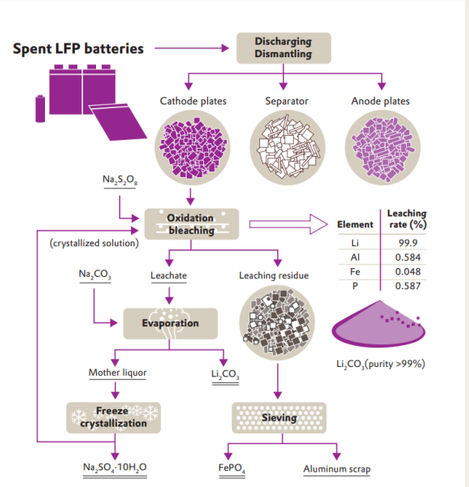


Persulfate

Persulfate is another peroxygen produced by Evonik. While hydrogen peroxide can either oxidize or reduce respective metals, persulfate provides a primarily oxidative pathway under conditions typically employed in LiB recycling. For example, this pathway is used as a highly efficient method to recover lithium from lithium iron phosphate (LFP) batteries.

Persulfate is available in several salts that are used in LiB recycling, including ammonium persulfate and sodium persulfate. The persulfate process leaches lithium quickly and efficiently from the cathode powder.

Recovering lithium from lithium iron phosphate (LFP) batteries



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Battery Recycling

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