Evonik Solutions for Battery Electric Vehicles

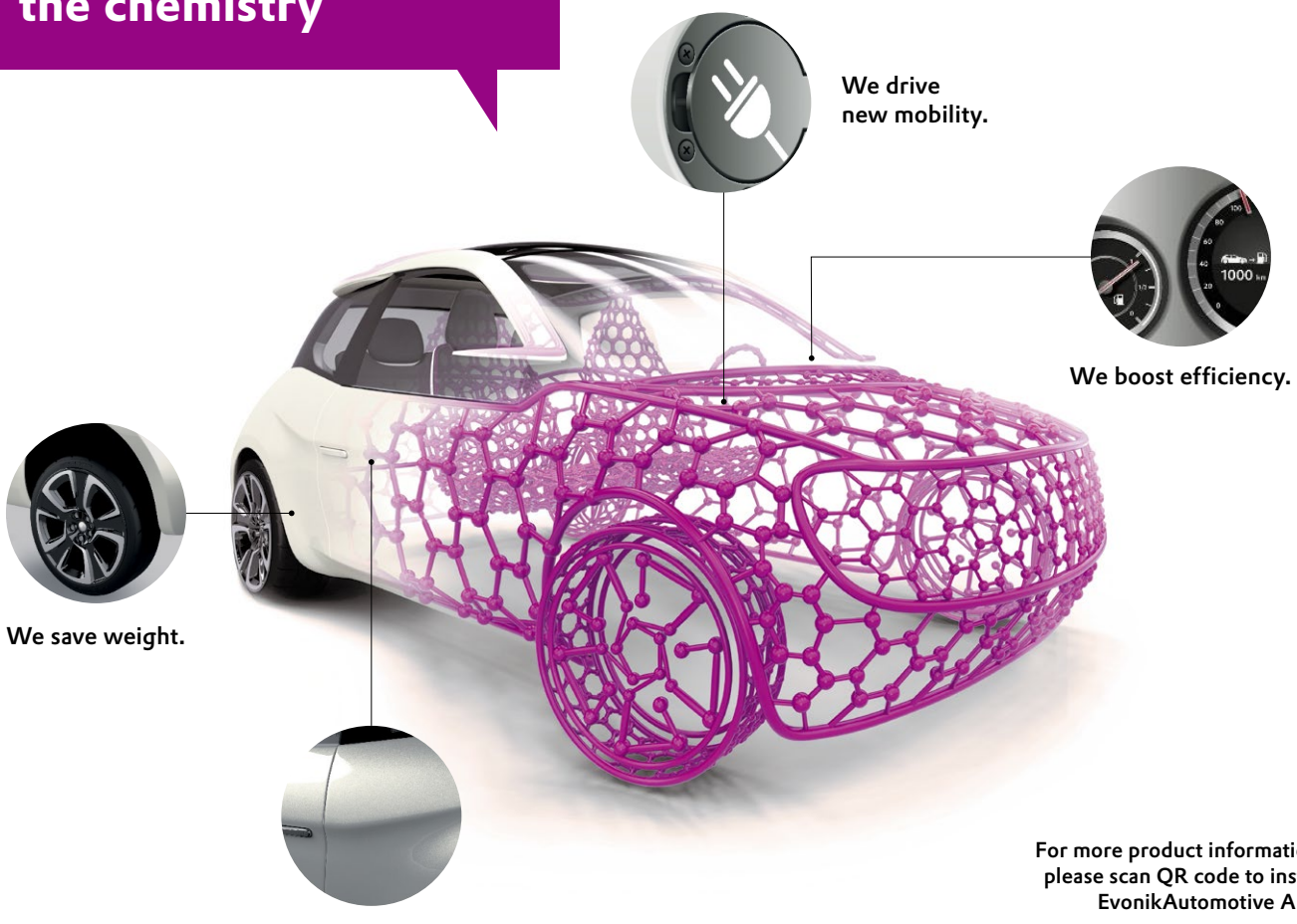
EVONIK
Leading Beyond Chemistry

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.

Innovate mobility — we provide the chemistry



For more product information, please scan QR code to install EvonikAutomotive APP.

iPhone Android

Evonik makes the electric vehicle batteries safer and long-living

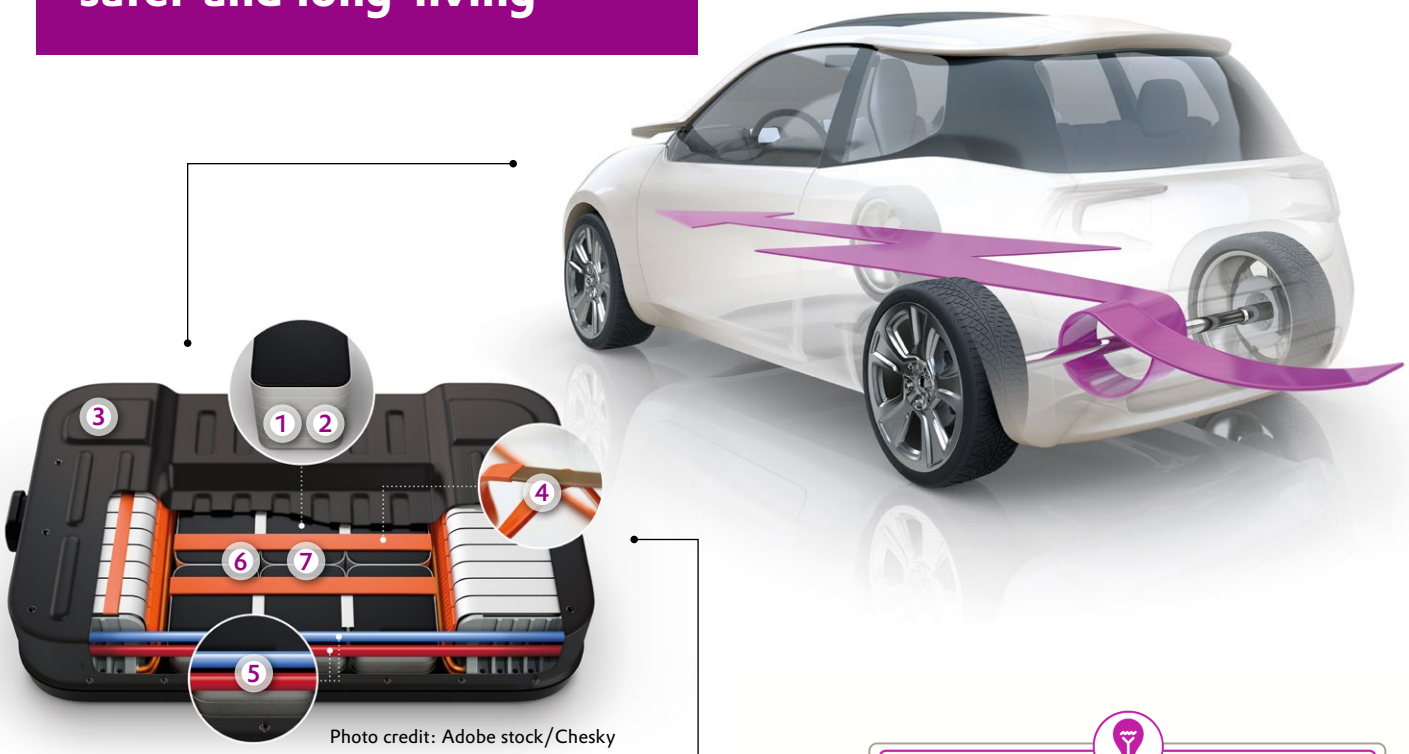


Photo credit: Adobe stock/Chesky

Our solutions for EV battery packs

1 **AEROXIDE® fumed metal oxides**
improve performance, life-time, and safety of Li-ion battery cells.

2 **TEGO® Surten E**
These process enablers help improving the production of Li-ion batteries achieving better electrical performance and lower overall costs.

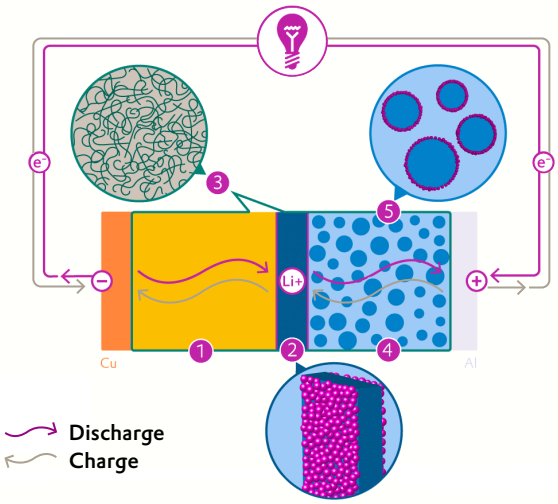
3 **VESTALITE® S, the new curing agent**
allows using optimized epoxy SMC technology for structural lightweight applications.

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

5 **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.

6 **Polymer VS and TEGOSIL®**
Silicone raw materials and additives for thermal management.

7 **TEGOSTAB® and POLYCAT®**
Silicone surfactants and amine catalysts to produce polyurethane froth foam for the protection of EV battery.



1 **Anode:**
Carbon-based material with addition of silicon

2 **Separator:**
microporous membrane coated with AEROXIDE®

3 **Gel polymer electrolyte:**
immobilized by functional AEROXIDE®

4 **Cathode:**
Mixed-oxide layer structure

5 **Cathode material**
specially coated with AEROXIDE®

Evonik provides various solutions for electric vehicle battery industry

Area		Products	Applications	Benefits	Page
Battery Pack Structure	Battery Box	Curing agent	Epoxy SMC based battery enclosure	Easy processing, lightweight design and low emissions	5
Energy Storage	Cathode	Fumed metal oxides (Al_2O_3, TiO_2)	Cathode Active Material (CAM) coating / doping	Protection of CAMs to enhance capacity retention / battery life	6 - 9
		Dispersant	Cathode slurry	Slurry viscosity reduction and stability improvement	
		Plasticizer	Cathode	Increasing cathode electrode layer flexibility	
	Anode	Silicon-based powders	Anode active material	Custom silicon-based anode materials with highly specific requirements	
		Dispersant	Anode slurry	Slurry viscosity reduction and stability improvement	
		Plasticizer	Anode	Increasing anode electrode layer flexibility	
	Separator	Fumed metal oxides (Al_2O_3)	Separator coating / incorporation	Improvement of thermal stability of separator	
		Low foaming, wetting agent	Ceramic slurry	Ceramic slurry surface tension reduction	
	Electrolyte	Fumed metal oxides (Al_2O_3)	Gel/polymer electrolyte	Realize semi-solid electrolyte for safety improvement	
Power Management and Connectivity		PA12	power busbars	For perfect electric insulation	10
Protection and Thermal Management		PA12	Cooling and heating line and connectors	Excellence performance together with production efficiency, lightweight and competitive system cost	11
		Silicone and filler treatment portfolio	Gap filler and thermal interface material	High flexibility of silicone formulation, improved thermal performance	12
		PU surfactant and catalyst	Cushioning and vibration absorption for battery packs	PU froth foam pad is both firm and compressible enough to extend the life of the battery	13
Battery Recycling		H_2O_2	Recycling of Ni, Co, Mn, Li	As the reducing agent to recover Li, Co, Ni, Mn in the leaching process	14
Contact us					15

Epoxy SMC based battery enclosure

Battery Pack Structure

VESTALITE® S curing agent offers a styrene free, high performance solution for sheet molding compound (SMC) material when combined with a liquid epoxy resin.

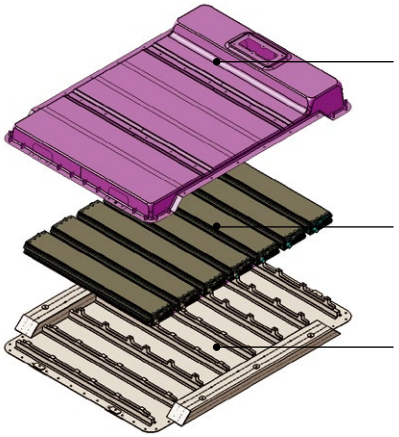
Its unique properties make it suitable for automotive applications in large scale automated manufacturing (e.g. battery enclosure).

CONSORTIUM APPROACH

Joint development of Evonik's Joint Venture Vestaro and further relevant partners along the electric vehicle battery value chain to achieve a holistic battery system solution.

CONCEPT DEVELOPMENT

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



HARDWARE DEMONSTRATOR

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

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

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.

AEROXIDE® fumed metal oxides as performance additives

Energy Storage

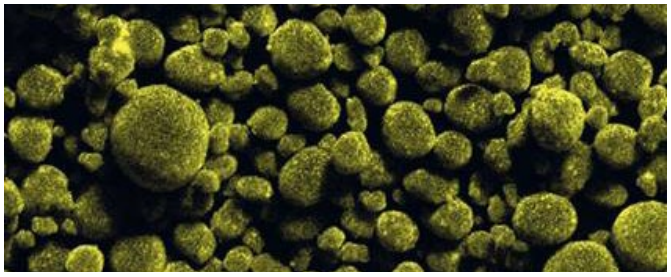
Product	Application
AEROXIDE® Alu 130, AEROXIDE® TiO_2 P 25	Protective dry coating for cathode active materials
AEROXIDE® Alu 65, AEROXIDE® Alu C 805 AERODISP® Ready to use dispersions	High performance LIB separator as coating or filler
VP AEROXIDE® Alu C 711	Functional additive in new electrolyte formulations

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.

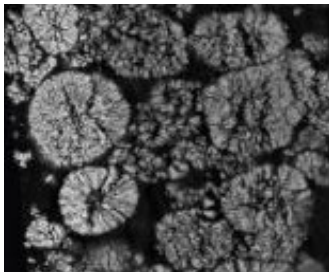
Dry coating for cathode active materials

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.

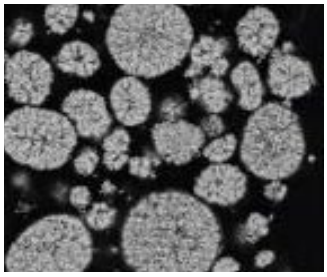
SEM: Al mapping of AEROXIDE® coated NMC particles



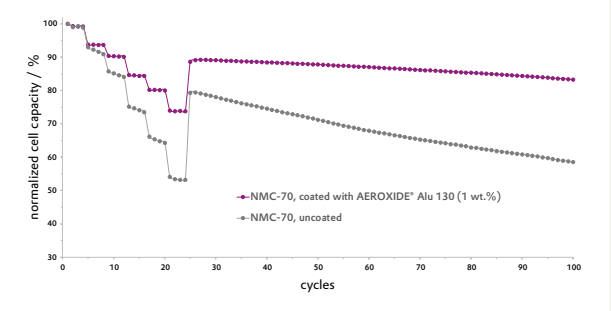
Cross section SEM imaging of cycled electrodes after 250 cycles



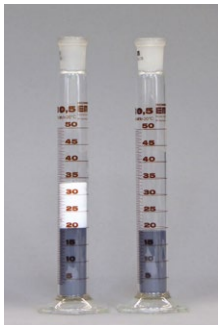
NMC-70, uncoated



NMC-70, **AEROXIDE®** coated



Example for stabilization of NMC-70.
Similar effect for other types of NMC (e.g. 811-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

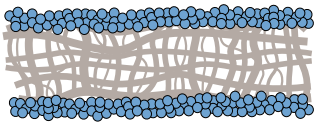
High performance LIB separator as coating or filler

Energy Storage

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

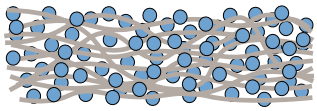


Ceramic particles on top of the microporous membrane

AEROXIDE®

AERODISP®

Particle incorporated

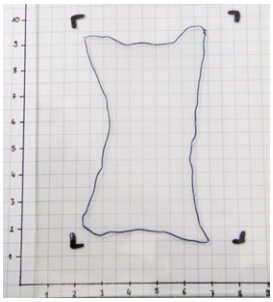


Ceramic particles throughout the whole interior of a polymer matrix

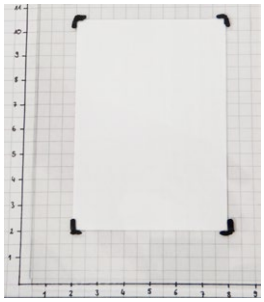
AEROXIDE®

Coating on Separator

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



Uncoated separator at 150°C



AEROXIDE® coated at 150°C

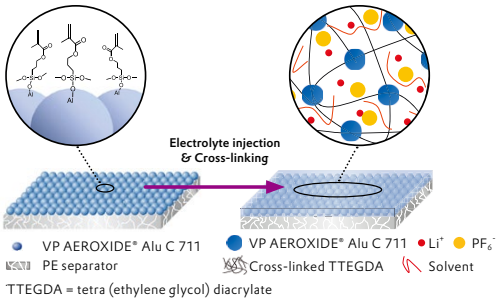
Ceramic filler inside separator

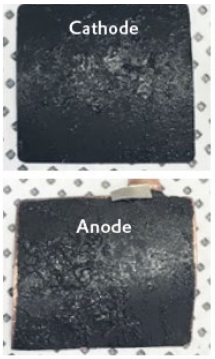
AEROXIDE® fumed alumina can also be used as ceramic filler inside separators, leading to excellent mechanical and thermal membrane properties combined with a high porosity.

Example: Manufacturing of an AEROXIDE® filled separator made by the dry process

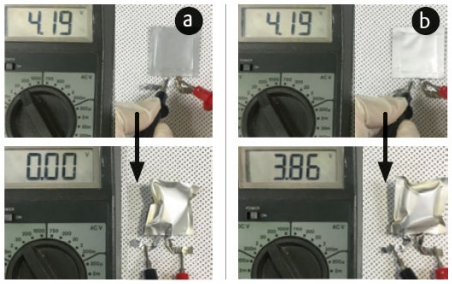
Functional separator coating: Formation of gel polymer electrolyte

VP 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 cross-liking 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.





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) VP 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

Silica

High performance silicon-based powders to boost the storage capacity of batteries

Energy Storage

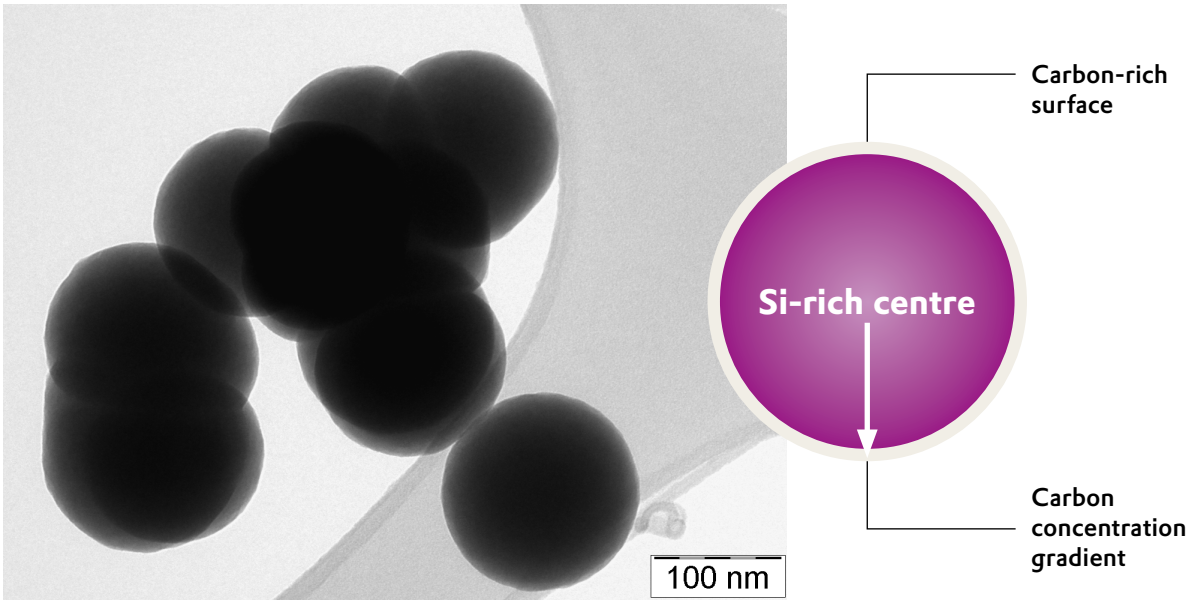
Product	Application
Silicon-based powders	High energy density lithium ion battery anodes

Silicon-based powders from Evonik are designed to provide high energy density and superior performance for lithium ion batteries. The high-performance anode material powders are produced by gas-phase synthesis. The powders consist of separated non-sintered spherical particles with size < 200 nm and are characterized by the amorphous structure.

In addition to our existing products, we develop custom silicon-based anode materials with highly specific requirements.

Si/C-based composite by Evonik

- Amorphous Si/C structure with unique carbon concentration gradient for superior stability
- Higher surface carbon content beneficial for oxidation protection and improved workability
- High specific capacity > 3,300 mAh/g
- High first cycle efficiency > 90 %
- Typical oxygen content < 1 wt. %
- Variable carbon content



Evonik Si/C composite powders: transmission electron microscopy image (left) and schematic representation of the Si/C structure with carbon concentration gradient (right).

Process enabler for LIB electrode and separator manufacturing

Energy Storage

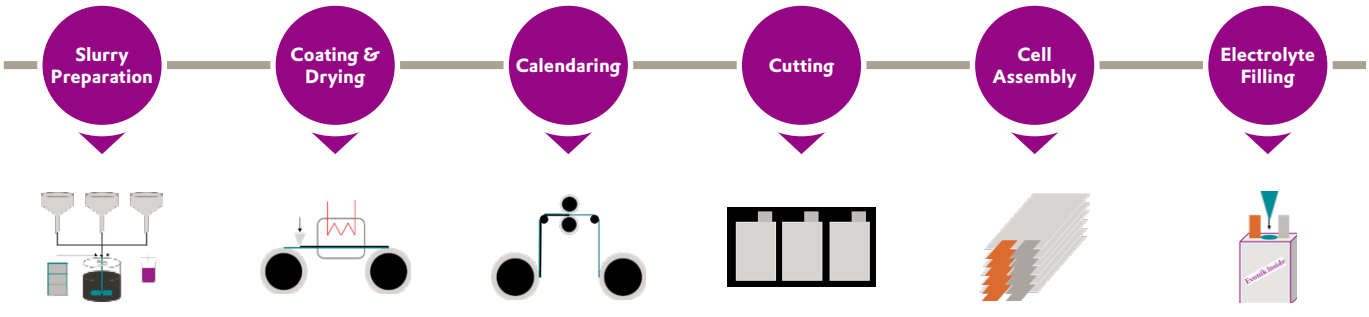
Product	Application
Dispersant	Cathode slurry, slurry viscosity reduction, uniform distribution of active materials Cathode slurry, viscosity reduction and uniform distribution of conductive materials
Plasticizer	Electrode, improve electrode layer flexibility and reduce electrode layer cracking
Low foaming, wetting agent	Separator, surface tension reduction for ceramic slurry

The process enablers 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 plasticizers.

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

Applications and key benefits

Separator coating	Wetting agent to ensure uniform coating and adhesive promo
Anode coating	Dispersant for slurry viscosity and grinding time reduction and uniform coating
Cathode coating	Plasticizer as anti-crack and swelling prevention
Electrolyte fillers	Liquid dispersant for next generation solid state electrolyte system
Calendaring	Defoamers to help avoid foaming and air-entrapment



Insulation for high voltage power busbars with VESTAMID® polyamide 12

Power Management

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.

A high level of fire protection is expected of the plastics used over the entire vehicle lifetime. In addition to this fire protection, insulative materials must also have outstanding dielectric properties. This applies particularly to power busbars in high-voltage batteries, which is why these 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.

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

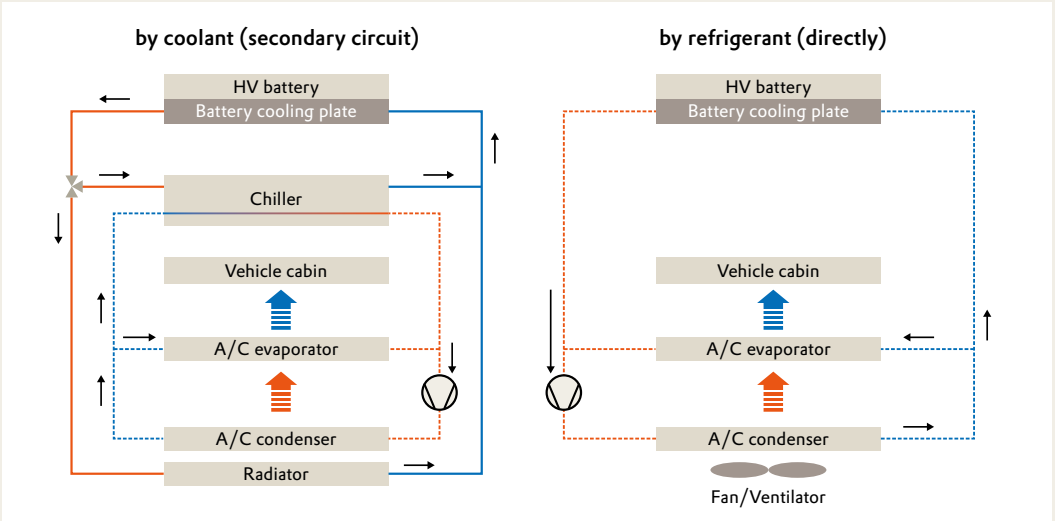
Properties	VESTAMID® PA12 compounds
Application voltage	high voltage up to 1000 V, low voltage
Busbar metal core	copper, aluminum, steel, … (also tin/nickel plated)
Coating material	PA12, various grades available
Coating thickness	0.5 – 1 mm
Coating process	extrusion
Color	orange (RAL2003), natural
Flame resistance acc. UL 94 (IEC 60695-11-10)	V2, HB
Halogen-free	yes
Temperature resistance	-40 to +125°C
Volume resistivity (IEC 62631-3-1)	10^{13} Ωm
Electric strength (acc. to IEC 60243-2)	> 25 kV/mm
CTI (IEC 60112)	up to 600

PA12 co-extrusion → forming and finishing → polymer testing

Thermal management with tubing systems from VESTAMID® polyamide 12

Protection & Thermal Management

xEV battery cooling architectures



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 cycle, 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.

Temperature range

-40°C – 90°C	Monowall tubing systems for BEV
-40°C – 110°C	Monowall tubing systems for PHEV
-40°C – 125°C	Multilayer tubing systems for ICE vehicles

Evonik cooling line solutions based on VESTAMID®

- Production efficient: Extrusion of MLT, thermoforming and insertion of quick connectors
- Lightweight: 30% to 50% weight reduction of complete system (MLT 8000 vs. AL/rubber)
- Performance: Excellent mechanical and chemical behavior as well as good anti-hydrolysis properties
- System material cost: Significant advantages compared to current concepts
- Packaging benefit: Less package space needed than for rubber hoses
- Excellent performance: Qualified for both, inside and outside battery pack application
- Proven: Serial use at OEMs globally

Silicone and filler treatment portfolio for battery assembly

Protection & Thermal Management

Silicone portfolio

Product	Application
Polymer VS silicones	Vinyl-terminated silicone portfolio with broad range viscosity starting from 20 mPas
Crosslinkers	Full range with different SiH contents & viscosity
Modifier 705 & 715	Di-function SiH structure to reduce crosslinking density and hardness
VQM 9xx series	Vinyl-functional QM resin for high mechanical properties and transparent formulations
TEGOSIL® Heatban	Heat stabilizer to improve formulation heat resistance up to impressive 300°C
TEGOSIL® FR 1000	Flame retardant co-compound for higher flame retardancy standard

Our full portfolio of silicone raw materials give high flexibility to build your formulation with desired viscosity, curing speed, hardness and high performance. We are willing to offer guiding formulations upon request.

Evonik solutions include:
Raw materials and additives for

- Gap fillers
- Thermally conductive adhesives
- Battery assembly adhesives

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®	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 to reach better thermal conductivity and flame retardancy
- Reduced formulation viscosity and water uptake
- Further increase of functional filler dosing level which enables even higher performance

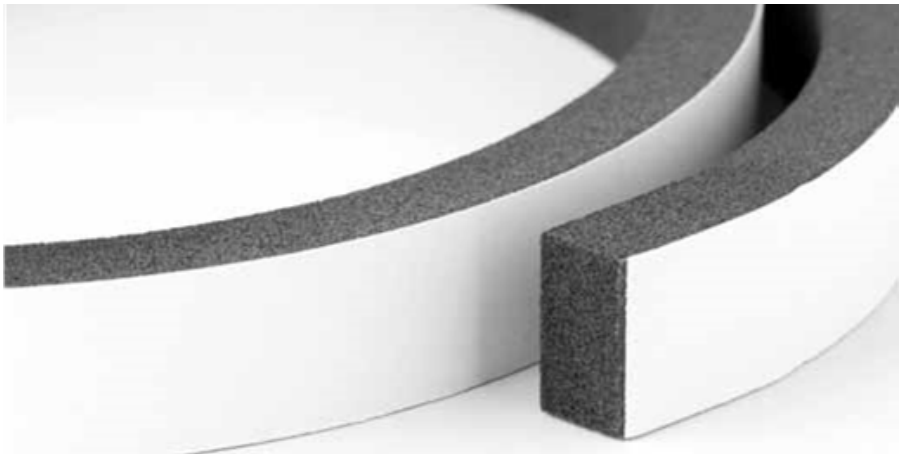
For other matrices, we also offer high performance raw materials including NANOPOX®, ALBIFLEX®, ALBIDUR®, for epoxy, NANOCRYL® for acrylic, and more. Please contact us for more information.

Surfactant and catalyst for polyurethane froth foam as battery pad materials

Protection & Thermal Management

Polyurethane froth foam is the ideal EV battery pad material

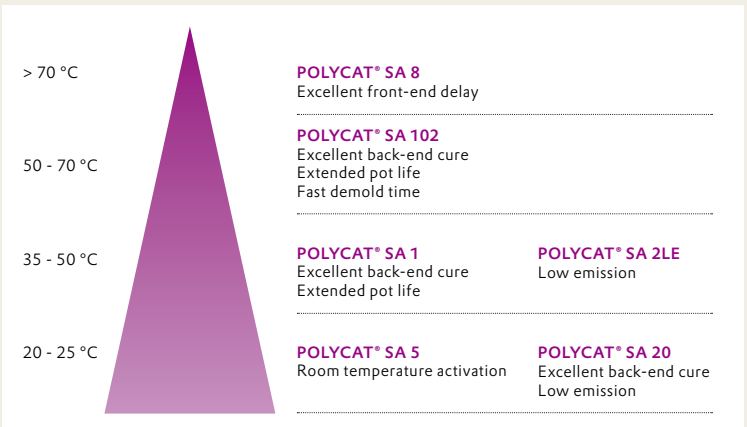
Battery packs must be protected from shock and vibration to ensure safety and long-term performance. PU froth foam pad is both firm and compressible enough to provide excellent cushioning and vibration absorption in order to extend the life of battery at a broad range of temperatures and harsh working environment.



Polyurethane froth foam is the ideal EV battery pad material

Evonik is the global leader in polyurethane additives. Our extensive product portfolio includes the innovative silicone surfactants and catalysts (amine and metal) needed for successful froth foam systems.

Product	Application
TEGOSTAB® B 8984	Highly potent froth surfactant that provides superior froth stability with a very fine and homogeneous cell structure. Ideally suited for low density froth foams with densities down to 200 kg/m^3.
TEGOSTAB® B 89120	Low VOC froth surfactant for low density froth foams with densities down to 200 kg/m^3. Provides superior froth stability with a very fine and homogeneous cell structure. Ideally suited for all polyurethane froth foam applications where VOC is an issue.
TEGOSTAB® B 89177	Froth surfactant for medium and high-density froth foam applications (400 – 800 kg/m^3). Can also be used as co-surfactant in combination with TEGOSTAB® B 8984 or TEGOSTAB® B 89120. Free of VOC.
POLYCAT® SA series	Heat activated catalyst with an excellent front-end delay with a wide range of thermo-activation temperatures. By choosing the right catalyst you can help to tailor a delayed reaction to optimize the formulation.



Polyurethane frothing technology requires the addition of unique additives. On the one hand, specially designed surfactants are needed to help stabilize the polyurethane system while also ensuring efficient frothing. These innovative surfactants help to regulate cell size and cell distribution of the foam. On the other hand, delayed action catalysts are required to improve the processing latitudes and process stability. These catalysts ensure that no reaction occurs during the frothing, delivery and final lay-down of the polyurethane mixture. Once the froth is applied, rapid curing is possible under heat.

LiB recycling using hydrogen peroxide as eco-friendly reduction agent

Battery Recycling

Product	Application
HYPROX®350, HYPROX®500	Recovery of Li, Co, Ni, Mn in the leaching processes of LiB recovery process;
CLAMARIN®350, CLAMARIN®500	Wastewater treatment to breakdown organics to reduce COD;

Lithium-ion Battery (LiB) is widely used in Electric Vehicles (EV) and smart portable devices, with more and more of them reaching its life expectancy, it is getting more and more critical to recycle the LiB in order to reuse the precious and rare metals (eg. Lithium, Cobalt) as well as addressing the sustainability and environmental protection perspectives.

The global LiB recycling market is expected to grow very fast.

Application overview

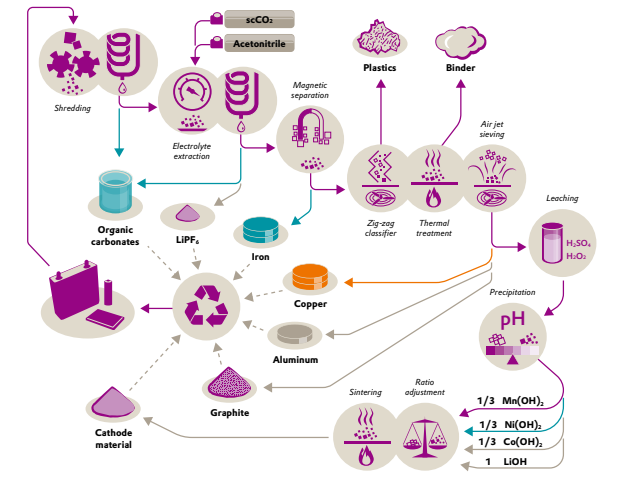
Among the various LiB recycling technology, a commonly widely implemented process is the so-called "Wet Hydrometallurgy" process. In this process hydrogen peroxide (H_2O_2) is used as a reduction agent in the leaching process, together with other acids (eg. H_2SO_4 , HCl or HNO_3) to:

- Transfer all Co(III), Mn(III), Ni(III) to Co(II), Mn(II), Ni(II), allowing better dissolution in the solution;
- Transfer all Fe (II) to Fe (III), allowing easier separation of iron from the solution;
- Increase leaching efficiency and shorten leaching time.

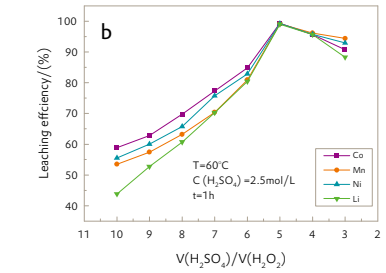
Compared with other reduction agent, hydrogen peroxide decomposes only into water and oxygen, therefore is considered more eco-friendly.

Hydrogen peroxide, with its activated radical group (-OH), can be used alone or in combination with Advanced Oxidation Process (AOP) technologies (eg. Fenton, UV, Ozone), to breakdown organics chains to reduce the COD of waste water.

Process flow scheme of wet hydrometallurgy LiB recycling



Effect of H_2O_2 on leaching efficiency



Source: Haiyang Zou, Worcester Polytechnic Institute, Development of a Recycling Process of Li-Ion Batteries

Evonik offers

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