Battery solutions with Kynar® PVDF
NOT ALL RESINS ARE EQUAL

For a couple of decades now, PVDF resins have proven themselves to be the best choice for highly stable binder resins – particularly for the cathode.

The best choice of PVDF resin is driven by two main factors:

- Proof of extreme performance under extreme conditions
- Peace of mind – assurance of global supply, quality, compliance, and commitment to ongoing development for the next generation of battery

Kynar® PVDF Resin - EXTREME PERFORMANCE

By nature, Kynar® PVDF is designed for extreme environments. The best evidence of this is the multiple outstanding track records of uses such as high durability skyscraper coatings (more than 50 years), subsea pipes for Oil and Gas (more than 26 years) and photovoltaic panel protection (more than 10 years).

As one of the pioneers in the evolving battery market, Arkema has quickly grown through intense innovation to its position today as a global reference and a leading supplier of high quality resins.

Kynar® Battery Solutions are represented by two flagship ranges – Kynar® HSV electrode binder resins and Kynar Flex® LBG resins for separator coatings.

In China each and every day, electric buses powered by batteries containing Kynar® PVDF travel more than 51,000 km!

Kynar® HSV Resin Series As Electrode Binders

- Fast dissolution, easy processing
- High adhesion
- Lower binder loading
- Lower swelling in electrolyte
- Lower electrode resistivity
- High voltage stability

Kynar® LBG & Flex® Resin Series for Separator Coatings:

- High adhesion to electrodes (wet and dry)
- High dimensional stability, controlled crystallinity
- Compatible with nano-ceramics
- Suitable for solvent and waterborne technology
- High voltage stability
The popularity of lithium ion batteries is growing at a rapid pace. While the market's initial growth came from consumer electronics for use in mobile phones, tablets, and power tools, the ongoing big boom comes from electric vehicles. The demanding automotive industry requires costs to be driven down and performance of batteries to significantly improve, while emphasizing the need for a consistent global supply chain. It's not an easy challenge.

Arkema is actively collaborating on projects for the next generation ultra high energy cathode, ultra high capacity anode, and technologies beyond Lithium ion batteries. Open innovation is key to our continued success.

Arkema has been a pioneer in the development of high performance PVDF resins and flexible copolymers for several decades. Our proprietary process allows careful tailoring of molecular weight, particle size, crystallinity, and functionality.

Emulsion PVDF was originally designed, more than 50 years ago for high end construction coatings where a small particle size is required to get a high level of gloss and smooth surface finish.

Higher Surface Area = Easier Dissolution = Faster Processing. Today, in battery applications, those small particles, combined with their unique aggregated structure, result in a fast dissolution rate into NMP or Acetone as opposed to large suspension particles where NMP diffusion into the beads may be extremely slow. The small particles are also key in enabling a revolutionary ‘dry process mixing’.

Emulsion polymerization can induce a higher level of head to head ‘defects’. This phenomenon is simply related to higher reaction temperature and can be seen in a slightly lower melting point and crystallinity versus suspension PVDF homopolymers. Inversion ‘defects’ actually increase the alkaline resistance of PVDF which is critical when using high Nickel NMC active materials.

For the sake of clarity, it is interesting to understand that playing on polymerization temperature using the emulsion process allows for the tuning or tailoring of the ‘defect’ level.

Molecular Weight Polydispersity

While Kynar® PVDF emulsion polymerization typically produces a mono-modal distribution of molecular weight, it also offers flexibility to synthesize grades with a tailored bi-modal and/or broad polydispersity, providing unique solutions to certain demanding applications.

Depending on the manufacturing process, it may be desirable to synthesize grades with a tailored polydispersity index, providing unique solutions to certain demanding applications. This ability to tailor the molecular weight distribution is a key benefit of Arkema’s process.

“By 2025, more than 50% of global lithium ion power will be driven by automotive and e-bus markets.”

Avicenne Energy
CATHODE BINDER RESINS

The surface of a lithium ion electrode is an extreme environment. Most conventional polymers would be quickly destroyed by the harsh electrochemical environment. But Kynar® PVDF has a proven legacy in some of the world’s most challenging applications, particularly when it comes to high purity industrial processes. Our extensive array of tailored grades demonstrate outstanding thermo-mechanical and electrochemical resistance over a wide range of application temperatures.

- Fast dissolution in manufacturing solvents, easy processing, high throughput, stable slurry viscosity
- High adhesion, even after huge numbers of charge/discharge cycles and wide temperature fluctuations, can be tailored by Arkema’s careful control of functionalization
- Lower polymer loading while maintaining adhesion, higher concentrations of active materials, low internal resistance, and high cohesion
- Lower swelling in electrolytes - can be tailored by Arkema’s careful control of crystallinity
- High purity and lot-to-lot consistency demonstrated by a tremendous global history in the Chemical Process Industry - including semiconductor, nuclear, potable water, and healthcare industries
- Best in class capacity retention
- Electrochemical resistance - stable over a wide voltage range (0 to 5 V Li+/Li)
- Thermal stability - stable, without thermal degradation up to 420°C as measured by TGA

Higher capacity, lower impedance

Kynar® HSV 900 Test Formulation at RT
3.5% Binder Loading

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Kynar® HSV 1800 Test Formulation at RT
2.5% Binder Loading

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“Cathodes typically account for 25% of lithium ion battery costs. Building a better cathode is the key driver for the continued success of the lithium ion revolution”

Lithium Investing News, 2017

Solution Viscosity of Kynar® Binders in NMP @ 25°C
**ACTIVE MATERIALS**

*Active materials* are constantly changing in the evolution of ever more efficient batteries. It is critical for binder solutions to provide high adhesion properties no matter what active material is being used. The Kynar® HSV resin series maintain excellent adhesion properties with:

1. LCO: LiCoO$_2$
2. LFP: LiFePO$_4$
3. LMO: LiMn$_2$O$_4$
4. NMC: LiNiMnCoO$_2$
5. NCA: LiNiCoAlO$_2$

**PEEL STRENGTH**

Higher adhesion at lower loading levels means higher energy densities. Lower binder loading allows increased active material content.

Swelling of the binder can have serious consequences in a lithium ion battery. Kynar® HSV resins demonstrate low swelling levels in common solvents — even at high temperatures (up to 80°C).

*Arkema is committed to an exciting future in binder innovation that will drive safer and higher performing cells. Arkema’s King of Prussia battery innovation hub in the USA leads the way. We invite customers to collaborate with us as we push the boundaries of cutting edge technologies - high nickel binders, waterborne solutions, dry process prototypes. Reach out to us today. We are ready to help.*

“Lithium Ion will surpass lead acid battery volume by 2020.”
Avicenne Energy, 2017
SEPARATOR COATINGS

With the development of larger and larger pouch cells as well as very high power cells, extremely high performance separators are needed to improve the battery abuse tolerance. Meanwhile, productivity to meet growing demand is under high pressure. Adhesive type separators dramatically reduce the cell assembly time, lowering the overall production cost.

Whether combined or not with Ceramics, Kynar Flex® grades and especially Kynar Flex® LBG grades allow an excellent balance between phase separation, adhesion to electrode (dry and wet), cohesion of the coating, and electrolyte uptake.

Separator coating being somewhat of “an art”, Arkema provides the most extreme range of Kynar Flex® copolymers allowing a broad selection of tailored solutions.

Separator coatings formulated with Kynar® LBG grade not only increase the mechanical properties and thermal stability of the separator in battery operation but more importantly, it hinders dendrite growth. It is designed to significantly improve the safety of large-format Lithium-ion batteries used in electric vehicles and high-power applications.

LEADERS IN WATERBORNE

Since 1965, Arkema has been a proven leader in PVDF technology. From the very beginning, we have been recognized as true pioneers in the world of extreme durability coatings. We also built our reputation as leading waterborne PVDF formulators. Our award winning Kynar Aquatec®-aqueous latex has helped coatings companies across the globe formulate field applied paints and coatings that can withstand several decades of the most harsh weathering and environmental abuse (www.kynaraquatec.com).

Our proprietary emulsion polymerization process lends itself to highly stable aqueous latex production that can be easily formulated, processed, and applied. We are already highly active in tomorrow’s aqueous binder program. Collaboration is welcome!

AN EXTENSIVE PORTFOLIO

Kynar® HSV 900
Kynar® HSV 1800
Kynar® LBG
Kynar® HSV 761A
Kynar® HSV 761A
Kynar® HSV 2751
Kynar® HSV 2801
Kynar® HSV 2821
Kynar® HSV 2751
Kynar® HSV 2821
Kynar® HSV 2501

Beyond PVDF

Arkema is also invested in battery innovation beyond PVDF resins. Speak to us today about our advances in Graphistrength® multi-wall low impedance carbon nanotubes (CNT), our next generation fluorinated electrolyte salts, as well as our extensive array of high performance polyamide resins for battery packs and cooling management. A new thermoplastic composite series (Rilsan® Matrix) was recently launched for its exceptional lightweight/strength combination.

“Electronics Solutions and New Energies represent 2 of Arkema’s 6 key innovation platforms”
Christian Collette, Arkema R&D Vice President
Arkema is committed to the explosive evolution that will drive this industry forward. And we offer proof:

- PVDF production in all three major global regions – Europe, Asia, USA with capacity expansions in each region
- A global technology hub in USA with regional technical satellites across the globe
- The world’s most famous brand
- A commitment to innovation – Reuters Top 100 global innovators - multiple winner of the Pierre Potier Award
- A long legacy of commitment to sustainable growth – biobased polymers, solar energy, cool roofing, and light weight automobiles
- A proven track record in batteries – from pioneers to cutting edge leaders
- Integrated from fluorspar to fluoro-gas to monomer to polymer
- Global PVDF capacity leader and leader in Fluorosurfactant Free (FSF®) PVDF emulsion polymerization

**GLOBAL SUPPLY AND SUPPORT**

“Supply of cathode materials could be outpaced by rising demand - especially from electric vehicles. Assurance of quality and uninterrupted supply is a critical component of the battery designer’s strategy.”

Lithium Investing News, 2017
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