

LITHIUM ION BATTERY

PVDF electrode binders & separator coatings



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KYNAR® PVDF

BATTERY CELL SOLUTIONS OVERVIEW

By nature, Kynar® PVDF is designed for extreme environments. The evidence is in its outstanding track record in use for high durability skyscraper coatings (>50yrs), subsea pipes for oil & gas (>25yrs), and solar panel backsheet protection (>10yrs).

The electrochemical environment in lithium ion batteries is extreme as well. Where oxidation and high voltage threaten the integrity of every material that is exposed, it is critical for engineers to design with purpose and caution when in the material selection process.

As one of the pioneers in the evolving lithium ion 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® PVDF battery solutions are represented by two flagship ranges:

- Kynar® HSV series for electrode binders
- Kynar Flex® series for separator coatings

A STRONG LEGACY

Arkema has been with the lithium-ion battery industry from the beginning. In supplying thousands of tons of material to cell manufacturers, we are deeply connected to the momentum of the market in providing high-performance materials. Arkema is the oldest and largest PVDF supplier in the world with production and support in the 3 major regions; key advantages that are highly valued by xEV and consumer electronics players across the world.

THE PRESENT

Our team is passionate and dedicated to supporting your battery developments. With three plants on three continents, our response and supply consistency can give you peace of mind. Our experts in material science follow the market demands very closely and our transfer of knowledge, expertise, and quality material is our commitment to you.

OUR FUTURE – LET’S GROW TOGETHER

The future is performance! Higher capacity, faster charging, more cycles, improved safety... But not just performance, also sustainability! We are committed to decrease the carbon foot print of lithium-ion batteries and some of our efforts include water-borne solutions and dry processing to reduce the use of NMP or avoid it altogether. Our expansive portfolio of fluoropolymers has made us a preferred partner in the development of next generation batteries such as solid-state batteries. And with our 3 plants worldwide, we are able to serve all new gigafactories in Asia, America, and Europe locally.

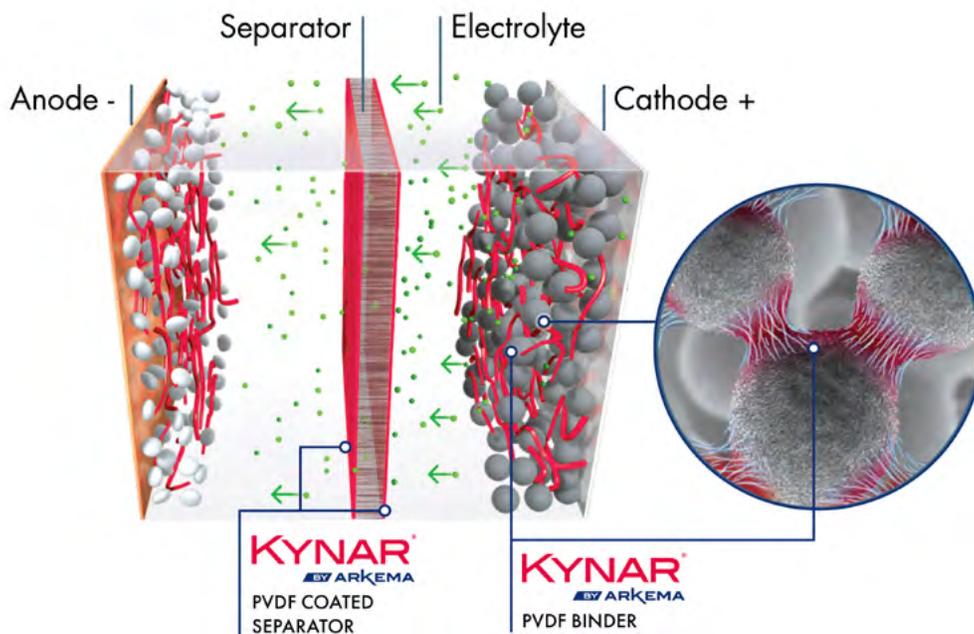
ELECTRODE BINDERS KYNAR® HSV SERIES

Electrode binder material choice is paramount in producing higher performance lithium ion batteries. The Kynar® HSV series is a tailor-made range of PVDF grades providing fast dissolution, easy processing, high adhesion, controlled swelling in electrolyte, lower electrode resistivity, and high voltage stability. See pages 4-7



SEPARATOR COATINGS KYNAR FLEX® SERIES

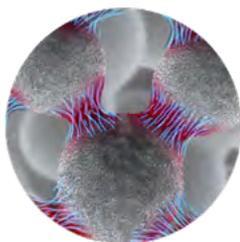
As the industry evolves to even larger and higher power cells, high performance separators are required to improve the battery performance, allow complex assembly, and expand the battery abuse tolerance. The Kynar Flex® series features a range of PVDF grades that provide great adhesion to the electrode (wet & dry), high voltage stability, high dimensional stability, and controlled crystallinity for both solvent and water-borne technologies. See pages 8-11



ELECTRODE BINDERS

KYNAR® HSV SERIES

The Kynar® HSV series of PVDF binders offers fast dissolution, easy processing, high throughput, stable slurry viscosity, and very high adhesion through many cycles and wide temperature fluctuations. Lower binder loading can be achieved while maintaining high adhesion through Arkema's careful control of **functionalization** of the binder resin. This allows for higher concentrations of active materials, lower internal resistance, and high cohesion across the electrode. The HSV series also exhibits very low swelling in electrolytes, which can be tailored by **fine tuning crystallinity**. These grades offer best-in-class capacity retention and electrochemical resistance with stability over a wide voltage range (up to 5V Li+/Li). Thermal stability is also stable across this range. With nearly 20 years of experience in the battery industry, we understand the importance of not only innovation but consistent quality and supply. Through many years of global experience in chemical processing industries (e.g. semiconductor, nuclear, potable water, healthcare), our team has developed industry-leading proficiencies in lot-to-lot consistency of very high purity PVDF.



❖ **KYNAR® HSV900** – the industry reference

❖ **KYNAR® HSV1800** – the 2nd generation

❖ **KYNAR® HSV1810** – the 3rd generation

PVDF is an electrochemically inactive material that plays an extremely active role in the manufacturing process of electrodes and electrode performance. The binder helps the battery to reach its maximum performance.

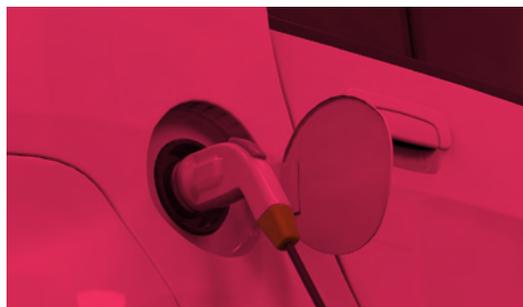
With high adhesion at lower loading levels, the Kynar® HSV series enables higher energy densities due to the increased active material content. HSV series binders also demonstrate low swelling levels in common solvents and electrolytes (even at high temperatures – up to 80°C). Binder swelling can have serious consequences in a lithium ion battery, so Kynar® HSV resins can ensure peace of mind.

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 series maintain excellent adhesion properties with: LCO, LFP, LMO, NMC, and NCA. Please contact our team for other materials.

Binder innovation is at the core of our strategy in the battery market. Arkema is committed to an exciting future in binder development that will drive safer, higher performing cells. We bring R&D close to our

customers with our network of research centers in **China, France, Japan, Korea, and United States**. We invite customers to collaborate with us as we push the boundaries of cutting-edge technologies (e.g. high nickel binders, waterborne solutions, dry process prototypes).



CONTINUOUS BINDER INNOVATION

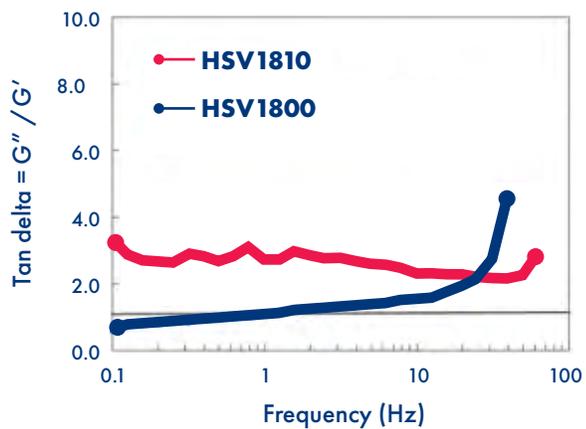
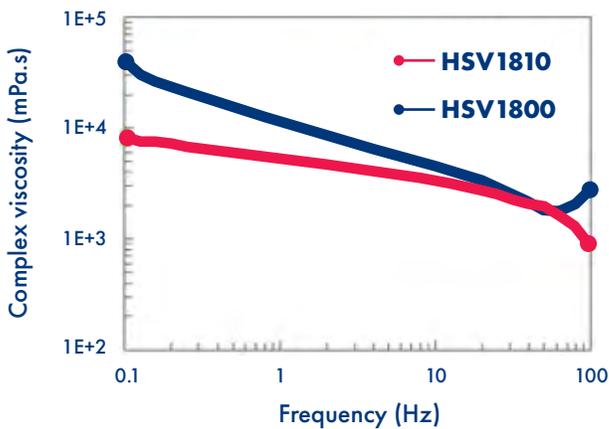
Adhesion is often seen as one of the most important properties of electrode binders, and over the years our team has continued to improve adhesion of our binders. The Kynar[®] HSV series really stands out as a high-performance, well-rounded electrode binder. In addition to great adhesion and **flexibility**, these binders have impressive **processing** qualities that we know are extremely important to efficiently produce lithium ion battery cells.

Relative adhesion on aluminum substrate



THE LATEST – KYNAR[®] HSV1810

Slurry processing window

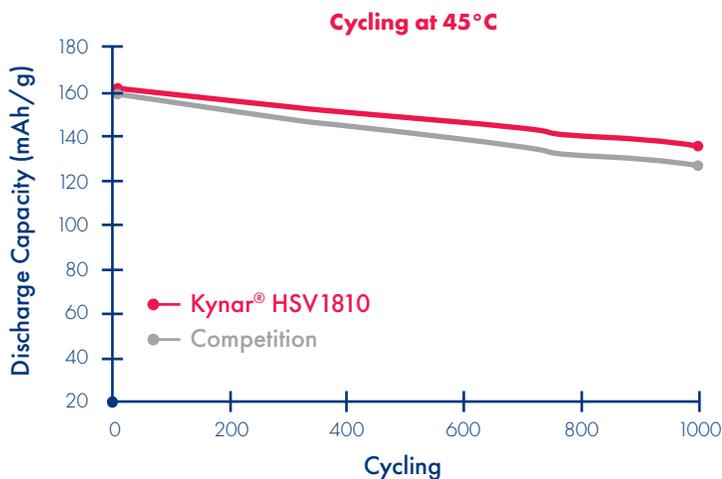
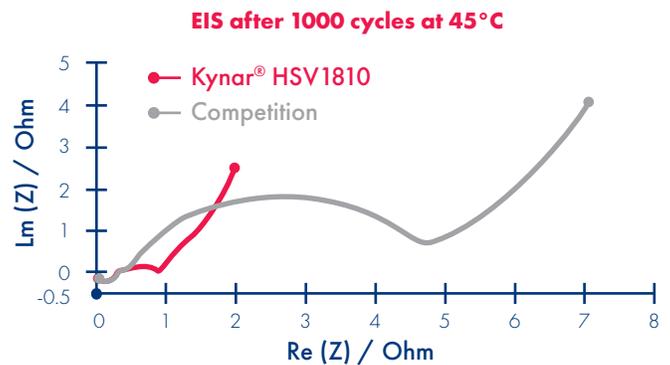
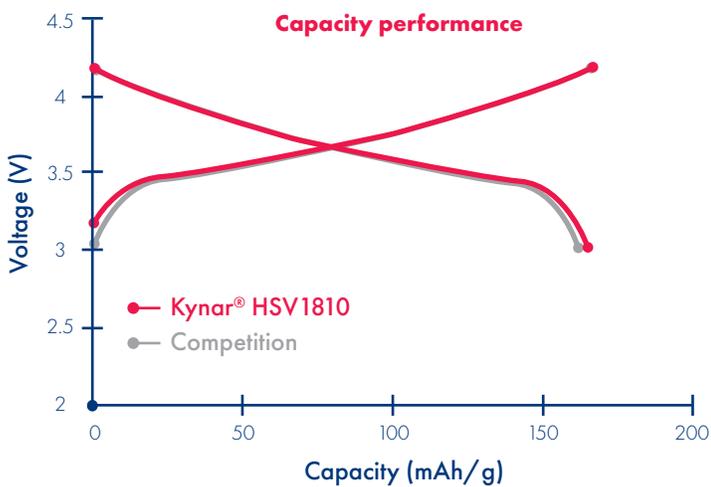


A wider processing window enables battery manufacturers to tune their processes and construct their cells using the most efficient methods possible. In the end, easier and faster processing can lead to cost reduction and higher throughput, and the new Kynar[®] HSV 1810 can help manufacturers achieve their stretch goals in operations.

ELECTRODE BINDERS

HSV1810 – EXCELLENT ELECTROCHEMICAL SIGNATURE IN Ni⁺ NMC

The cell performance while using Kynar[®] HSV1810 is simply excellent. This is the result of being able to reach the desired level of dispersion of the cathode components and the properties of the binder itself. With multiple formulations and processes, Arkema has developed an extensive knowledge to help each customer reach the maximum potential of our Kynar[®] HSV series.



GREEN MANUFACTURING – WATER-BORNE & DRY PROCESS

Why green?

It's apparent that ideas like "going green" and "being more sustainable" are the paradigm shift of our generation. No longer do we look at products and services without considering, whether brief or exhaustive, the environmental impacts of said products and services. This cultural awakening is especially true in the material world. Understanding where materials come from, how they are processed, and what lasting effects they will have on the world is a new expectation of engineers beyond evaluating physical and mechanical properties. For lithium-ion batteries, specifically electrode and separator coating manufacturing, this means crafting safer processing conditions and eliminating harmful chemicals.

Battery value-chain

Consumer electronics and automotive companies may be the public facing entities of the battery value-chain, but they aren't the only players responsible for creating more

green manufacturing processes for batteries. At Arkema, we are deeply committed to helping our customers push towards more sustainable solutions and the lithium-ion battery industry is no exception. Our global R&D team continues to work hard in developing innovative material solutions to not only produce higher performance batteries, but more sustainable ones too.

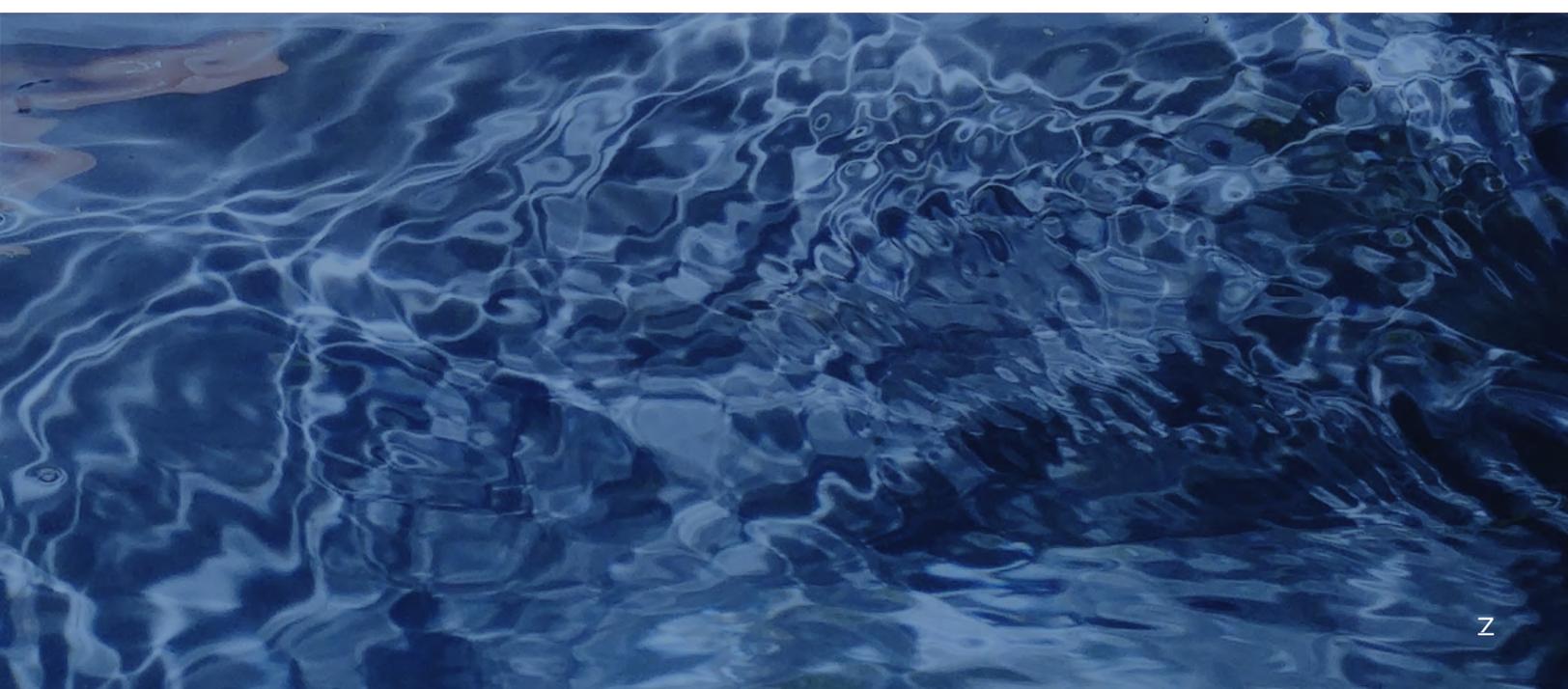
Green processes

For cell manufacturing, two new processes are helping move the industry towards more sustainable practices: (1) Switching from Organic Solvent-borne to **Water-borne materials**; and (2) **Dry processing**.

Water-borne electrode binders like Kynar® PVDF LX technology can help eliminate the harmful organic solvent, NMP, while leaving the general process of mixing, coating, and drying virtually unchanged. Kynar® latexes under the LX technology have very high stability and low foaming, which produces more efficient and

consistent processing resulting in the high-performance expected from any Kynar® PVDF grade.

As in a water-based system, the mechanism to develop adhesion in a dry process is completely different than in a solvent-based one. In the new mechanism, close to a dot-to-dot one, the particle size is crucial. Through our dedication to emulsion polymerization, Arkema is bringing products to the market with the right particle size, particle structure and particle size consistency! Our powders, close to 10µm with a raspberry-like structure, can be evenly dispersed through dry mixing and will impart the necessary level of adhesion/cohesion in the electrodes.



SEPARATOR COATINGS

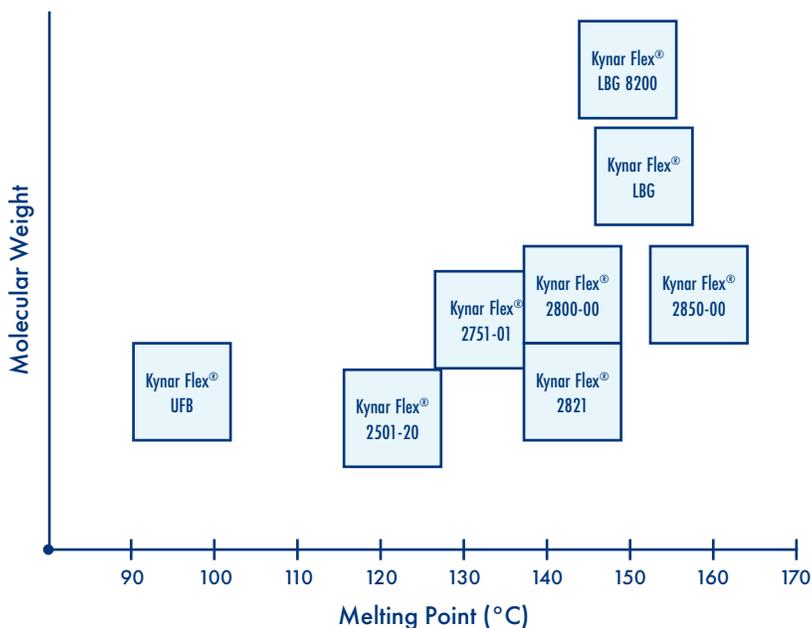
KYNAR FLEX® SERIES

The Kynar Flex® copolymer series provides a wide range of performance similar to the HSV series, but this range is dedicated specifically to separator coatings. With an accelerating market, productivity to meet growing demand is under high pressure. One way to dramatically reduce the cell assembly time and lower overall production costs is to use adhesive-type separators. The Kynar Flex® separator coating series demonstrates outstanding adhesion while maintaining a high degree of flexibility. Regardless of being combined with ceramics, Kynar Flex® grades allow an excellent balance between phase separation, adhesion to electrode (dry and wet), cohesion of the coating, and electrolyte uptake. With separator coatings being somewhat of an “art,” Arkema provides the most comprehensive range of polymers, allowing a broad selection of tailored solutions.

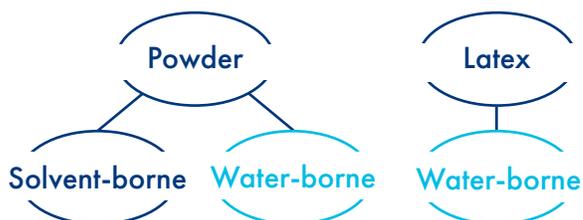
“With separator coatings being somewhat of an “art,” Arkema provides the most comprehensive range of polymers, allowing a broad selection of tailored solutions.”

–Thomas FINE

Global Battery Market Manager



VERSATILITY FOR SOLVENT OR WATER-BASED COATING

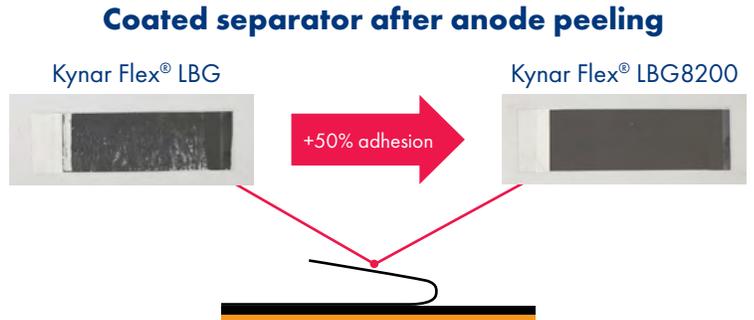


- ❖ **KYNAR FLEX® LBG** – the first separator coating solution
- ❖ **KYNAR FLEX® LBG 8200** – the portfolio extension
- ❖ **KYNAR FLEX® LBG 2200 LX** – the water-borne solution

EXTENDING THE RANGE

Kynar Flex® LBG 8200 effectively increases adhesion by 50% compared to the original Kynar Flex® LBG. With an increased molecular weight and subtle functionalization, Kynar Flex® LBG 8200 extends the performance range of the LBG series for separator coatings.

Property	LBG	LBG 8200
Molecular weight	Medium	High
Functional	No	Yes
Melting point	152°C	150°C



❖ DRY ADHESION to electrode

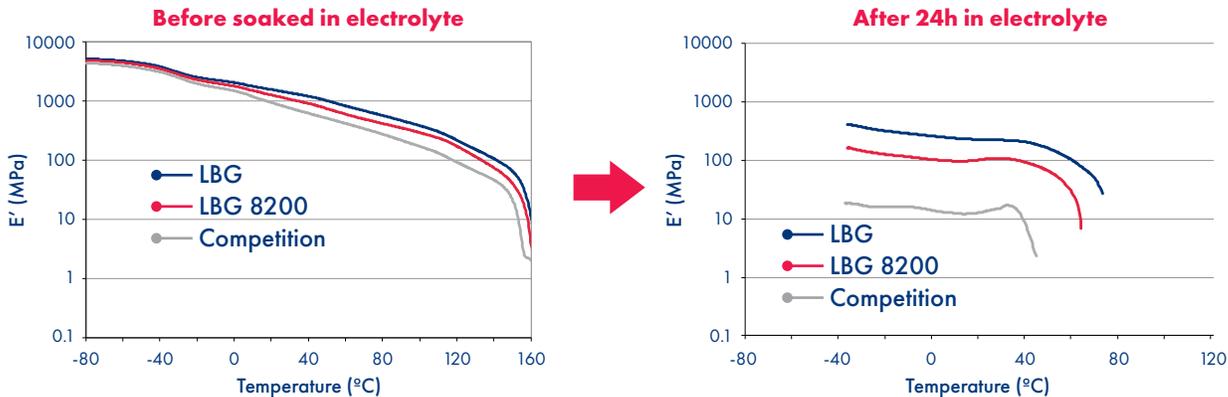
- Better processing/handling
- Allows complex structure

❖ WET ADHESION to electrode

- Better cell performance
- Better safety

Dynamic mechanical thermal analysis of separator coatings soaked in electrolyte

Thermal-mechanical behavior in flexion at 1Hz-2°C/min



In electrolyte, the Kynar Flex® LBG series has a wider temperature operating window and a stronger mechanical response than competitive grades.



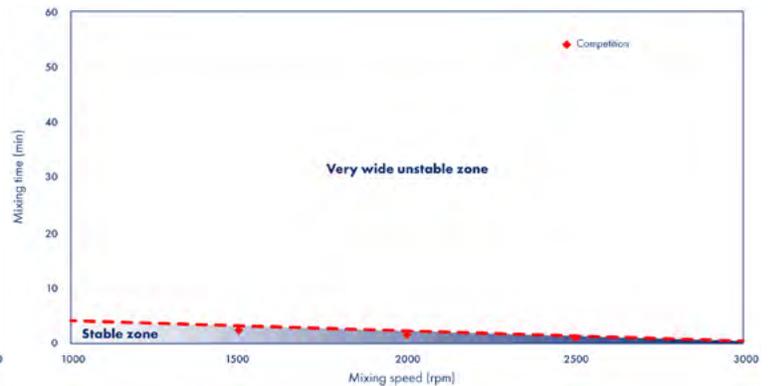
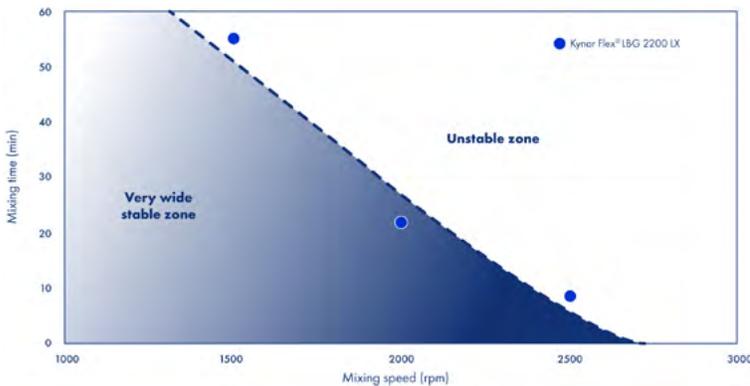
SEPARATOR COATINGS

WATER-BASED SOLUTIONS

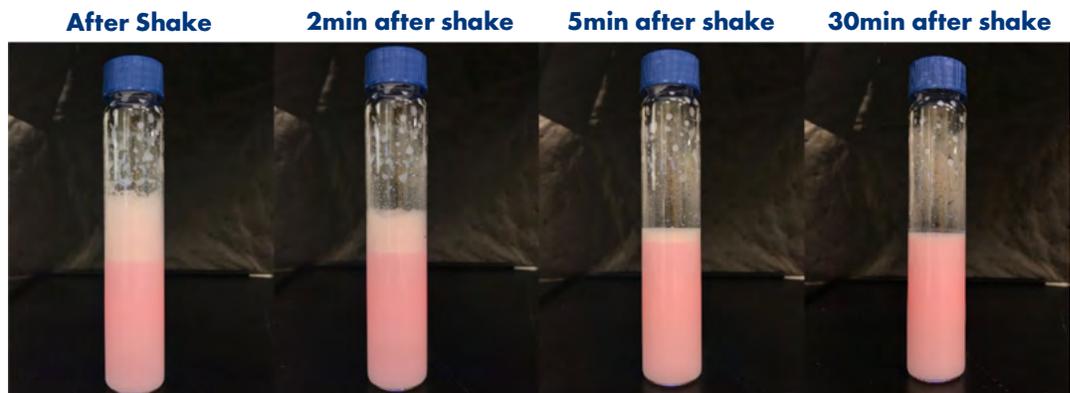
KYNAR FLEX® LBG 2200 LX (LATEX)

LX technology is the most stable PVDF latex that can be shipped all over the world. With Arkema's decades of expertise in water-borne, latex coatings (Kynar Aquatec®), our researchers now extend the LBG separator coating series to water-based Kynar Flex® LBG 2200 LX. This new grade also has unmatched shelf-life stability with very high solids content. Arkema is committed to developing sustainable solutions and this new water-based technology for lithium ion batteries is the result of our dedication.

Latex shear stability – Onset of thickening



Low foaming after shaking



❖ **The latex***, as seen in the images above, illustrates that after only 5 minutes, foaming is almost entirely gone, and then after 30 minutes foaming has completely subsided.

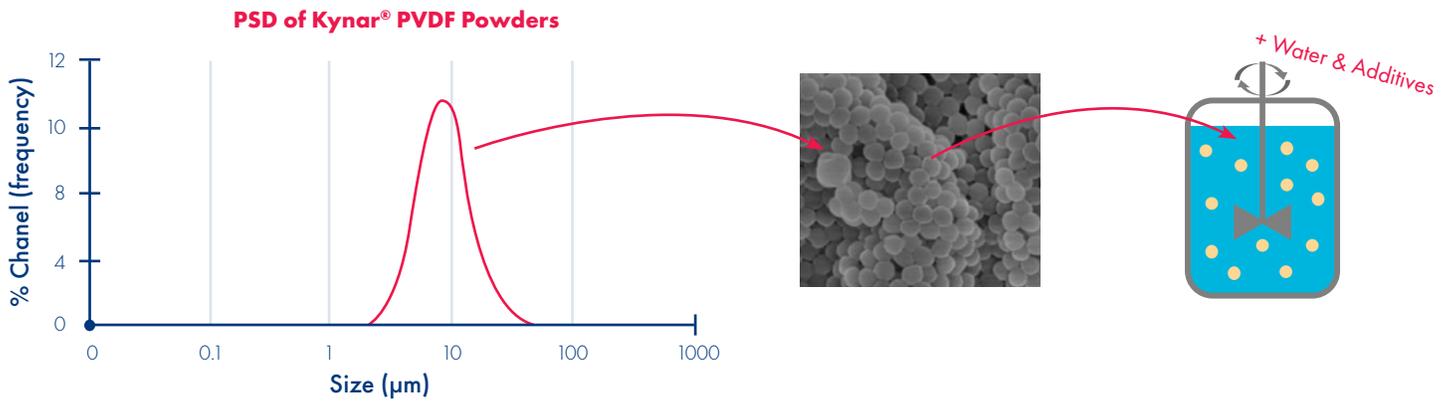
*Pink color added for demonstration purposes only

WATER-BASED SOLUTIONS

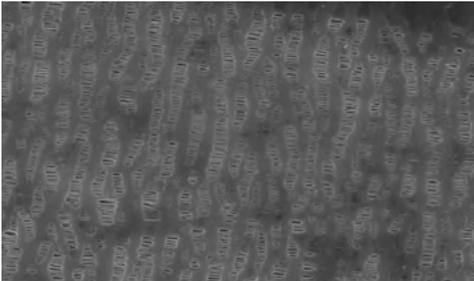
KYNAR FLEX® LBG (POWDER)

Thanks to our **proprietary emulsion process**, Arkema is able to supply the separator coating market with powders dialed in to the perfect particle size. Indeed, size is of the essence when dealing with water-based formulations. For decades, our super-fine Kynar Flex® PVDF powders are THE reference for separator coatings that enable outstanding performance.

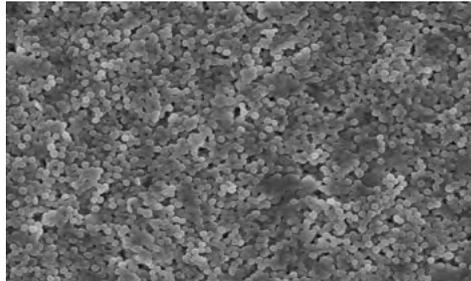
Ingredient	Composition
Kynar® LBG	28.5%
W&D Additives	1.7% (as effective material)
Defoamer	0.5% (as delivery form)
Water	69.3%



Uncoated surface x10k



Coated surface x10k



- Better electrolyte wetting
- High adhesion to electrode
- Lower resistance



Global Manufacturing, Technical Support, and R&D

Europe

 **HQ** Colombes, FR

 **Tech Support** Serquigny, FR

 **Plant** Pierre-Bénite, FR

Americas

 **Tech Support** King of Prussia, PA

 **Plant** Calvert City, KY

Asia

 **Tech Support** Changshu, CN

 **Tech Support** Kyoto, JP

 **Tech Support** Seoul, KR

 **Plant** Changshu, CN

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