

ARKEMA

HIGH-PERFORMANCE  
SOLUTIONS FOR  
LITHIUM-ION  
BATTERIES

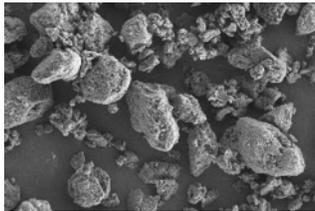
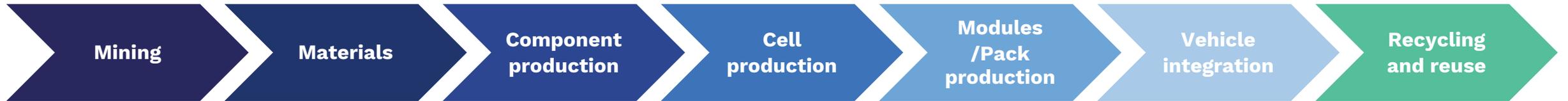




1

# Arkema In The Battery Value Chain

# Arkema in the battery value chain



**Mining companies**

**Chemical companies**

**Batteries companies**

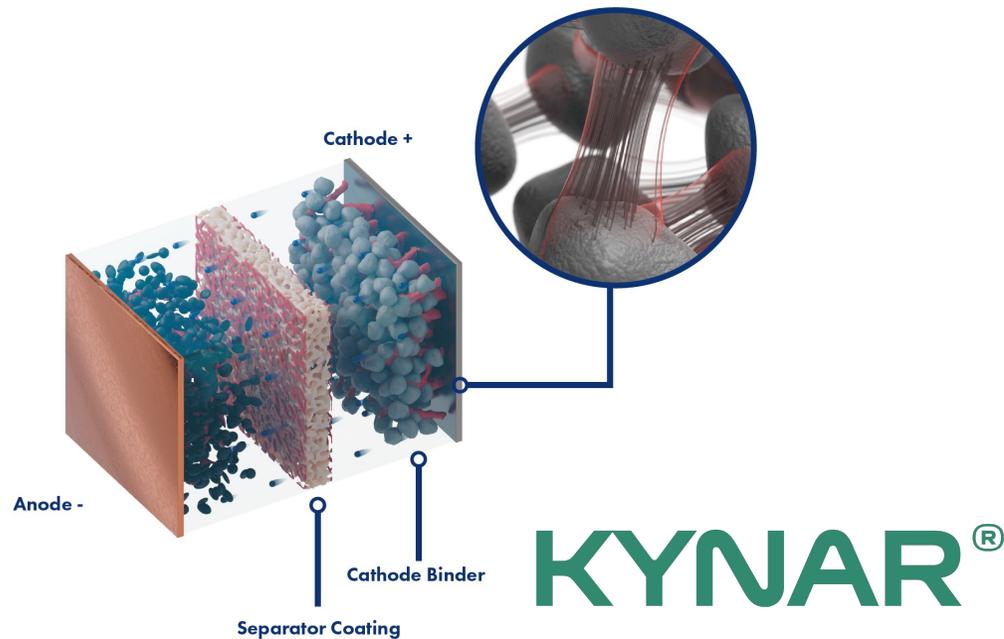
**OEM**

**All**

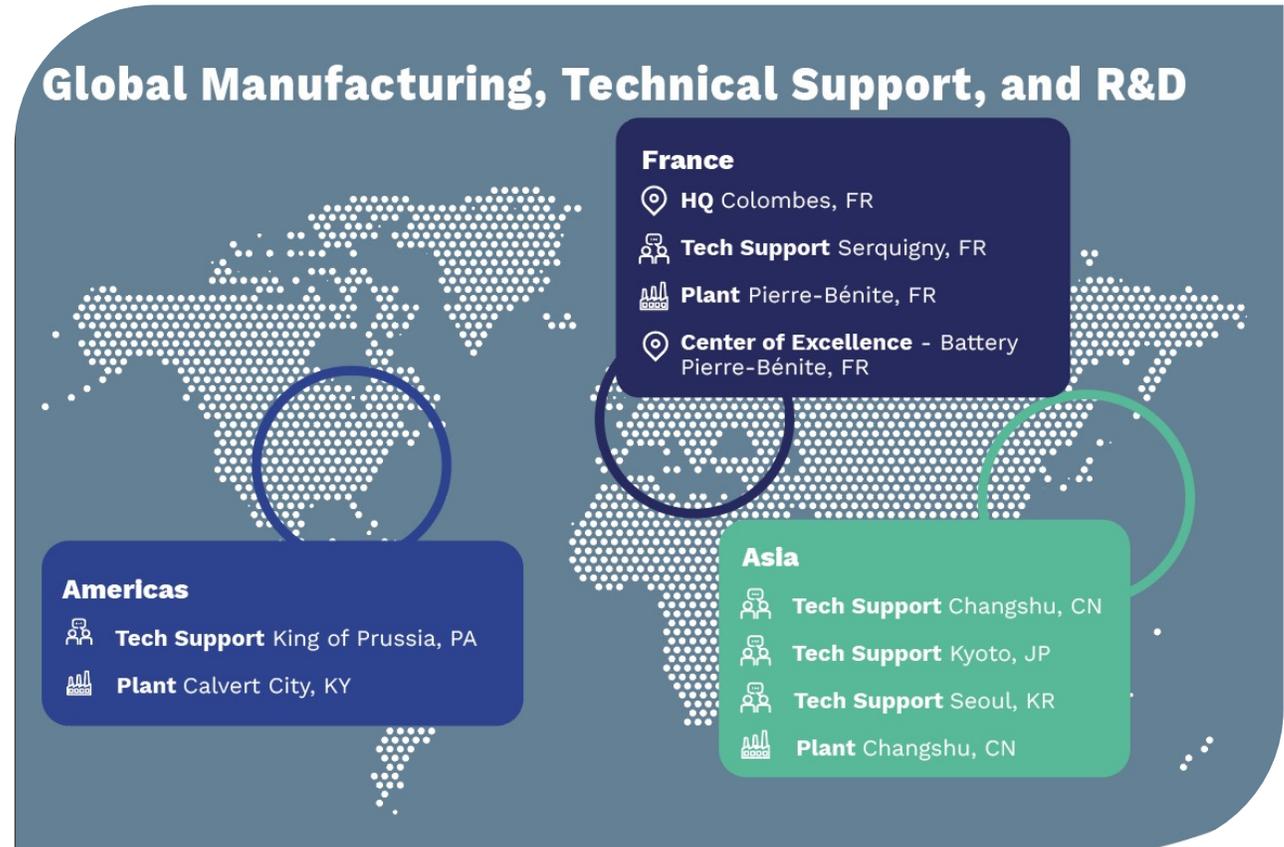


# Arkema's materials for battery cells

- Arkema #1 PVDF producer since 1963
- 1996: Start of sales of Kynar® PVDF for lithium batteries
- 3 plants: US, France, China, to serve the region from the region Battery R&D centers in USA, France, China, Korea, Japan
- 7 capacity expansions in the last 10 years



**KYNAR®**



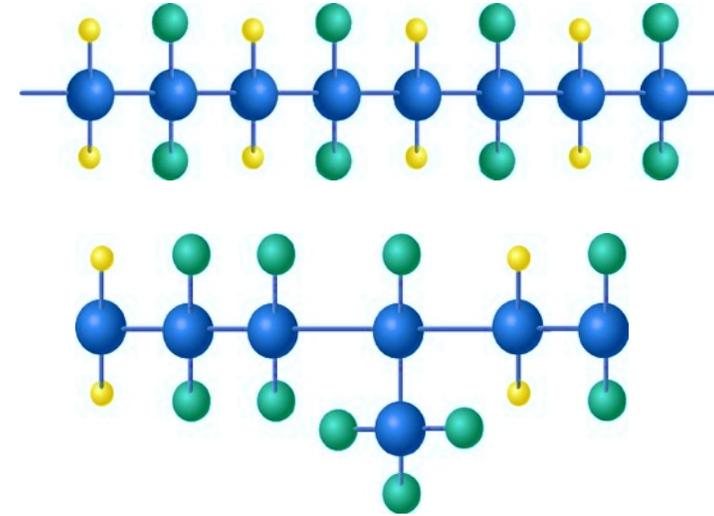
# What is Kynar<sup>®</sup> PVDF?

## KYNAR<sup>®</sup>

Thermoplastic homopolymer PVDF based on (VF2)

## KYNAR FLEX<sup>®</sup>

Thermoplastic copolymer PVDF based on (VF2 + HFP)



EXTREME UV  
RESISTANCE



EASY TO  
PROCESS



COMPLIANT  
CERTIFIED,  
WIDELY  
SPECIFIED

HIGH PURITY

HIGH  
WHITENESS

RADIATION  
RESISTANCE

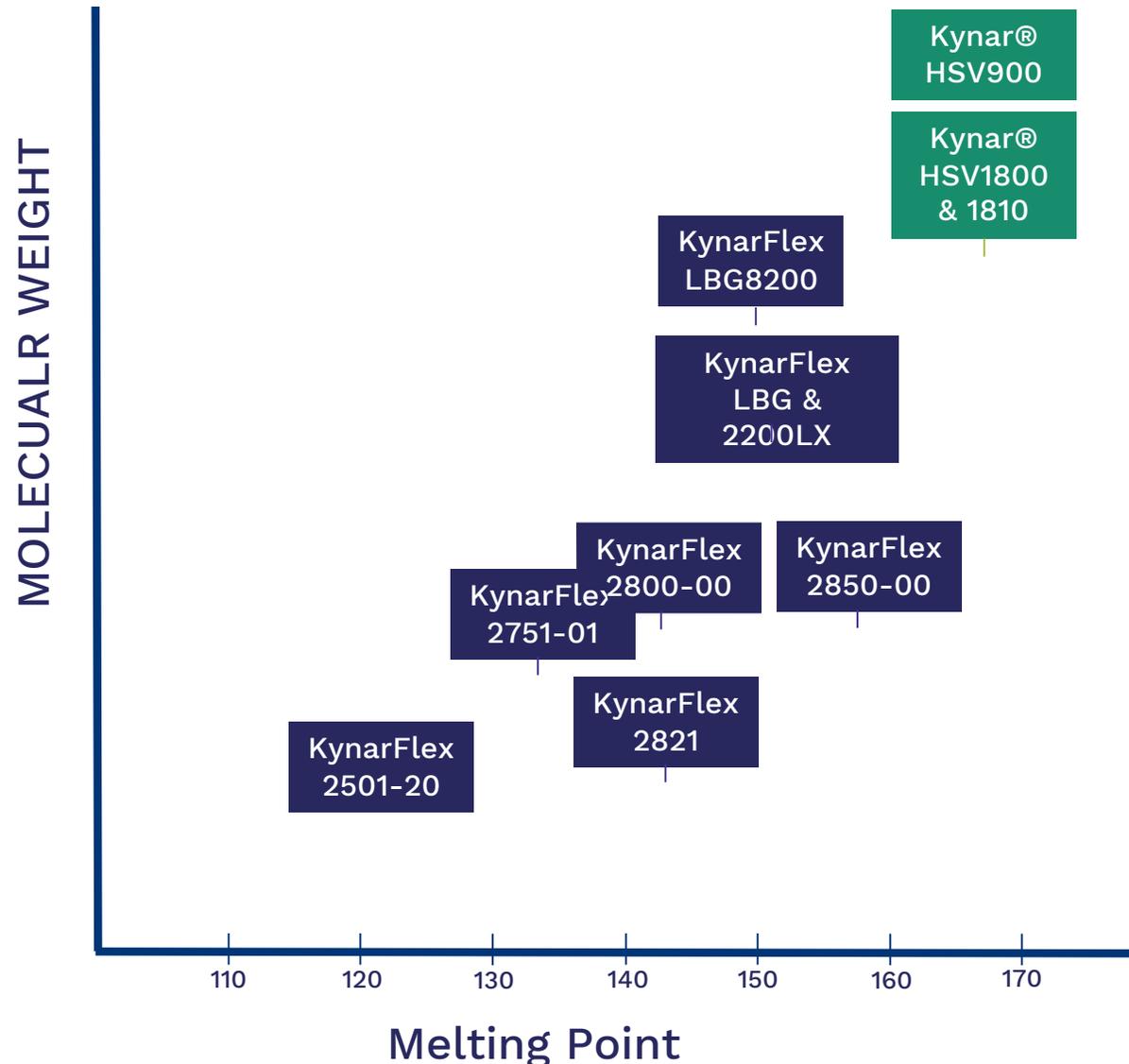
ELECTRO-  
CHEMICAL  
STABILITY



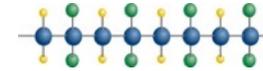
EXCELLENT  
FLAME AND  
SMOKE  
PROPERTIES

EXTREME  
CHEMICAL  
RESISTANCE

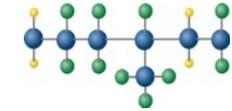
# Kynar® PVDF portfolio for battery applications



## Homopolymers



## Copolymers



Very broad range of fluoropolymers as electrode binder and separator coating application

## Functional Fluoropolymers:

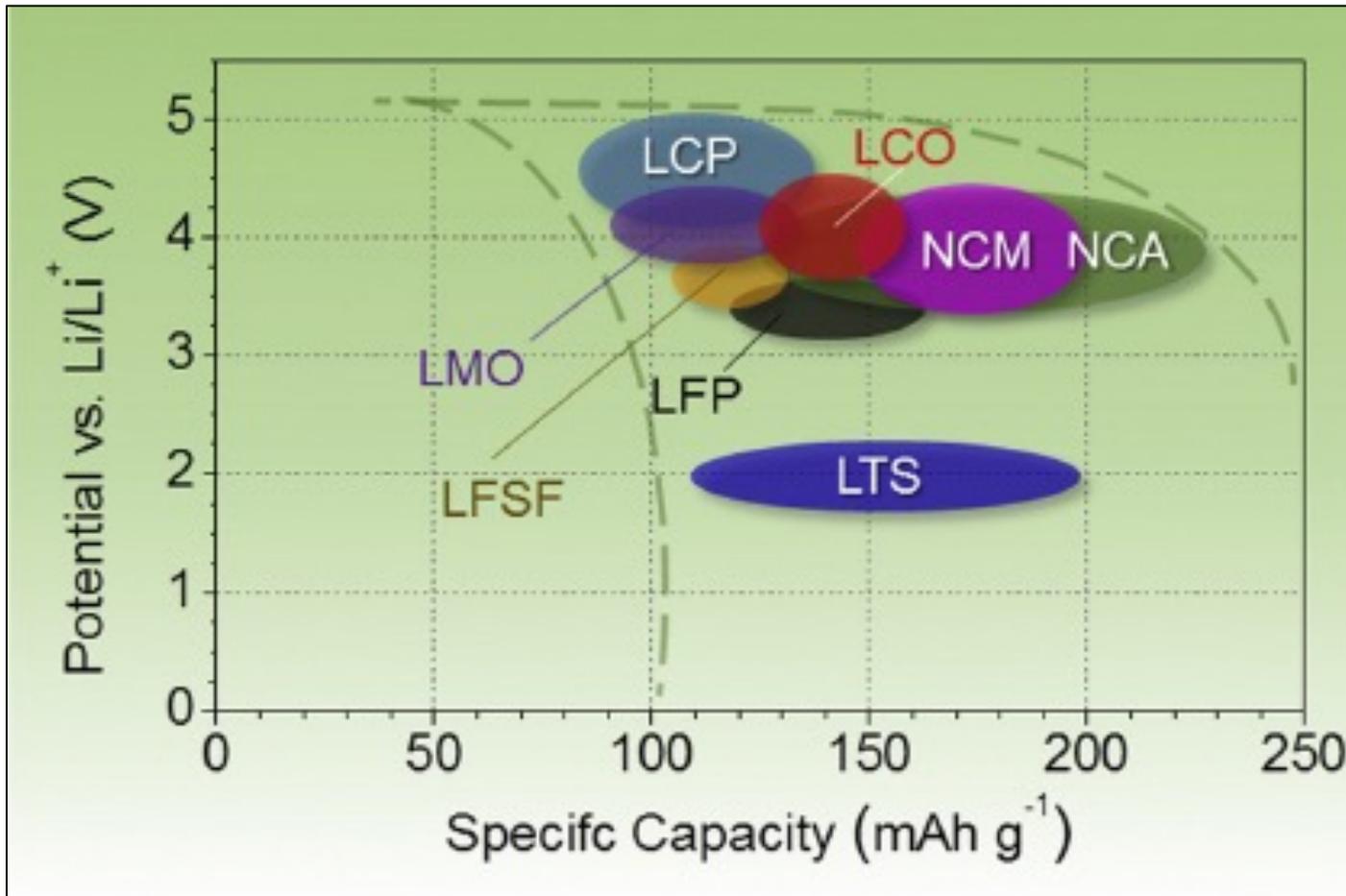
- Kynar® HSV1800
- Kynar® HSV1810
- Kynar® LBG8200

New latex technology for separator coating and WB cathode binder.

A large, white, sans-serif number '2' is positioned on the left side of the slide. The background consists of a gradient from dark blue on the left to bright green on the right, with a wavy, liquid-like texture. A thin white vertical line is located to the right of the number '2'.

Focus On Kynar<sup>®</sup> HSV  
Series For Cathode  
Binder

# Trends in cathode active materials



**LFP** - Lithium iron phosphate

**NCA** - Lithium nickel cobalt aluminium oxide

**LCO** - Lithium cobalt oxide

**NCM** - Lithium nickel cobalt manganese oxide

**LMO** - Lithium manganese oxide

**Market to shift towards higher Ni materials for higher capacity and voltage**

# Kynar<sup>®</sup> PVDF solutions for high energy density NMCS

## HSV900

### KEY FEATURES

- **Super high Mw Kynar<sup>®</sup> PVDF**
- **Good Adhesion**
- **Stable slurry behavior**
- **Low internal resistance**
- **Market reference for LCO, LFP and NMC111**

## HSV1800

### KEY FEATURES

- **Functionalized Kynar<sup>®</sup> PVDF**
- **Designed for Ni+ NMC, LTO and LFP**
- **Enhanced adhesion**
- **Fast dissolution in NMP**

## HSV1810

### KEY FEATURES

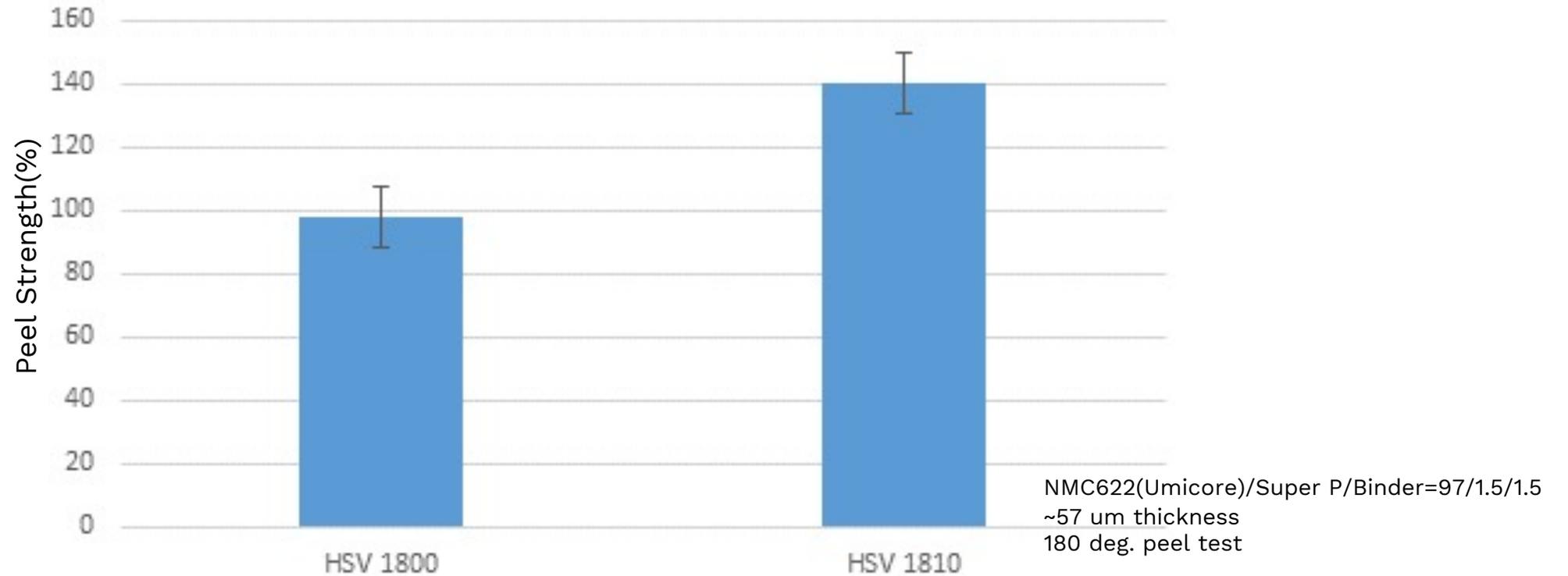
- **Functionalized Kynar<sup>®</sup> PVDF**
- **Designed for Ni+ NMC**
- **Enhanced adhesion**
- **Fast dissolution in NMP**
- **Wider processing window in Ni+ NMC**

Each Kynar<sup>®</sup> HSV grades has its own value !

**New Kynar<sup>®</sup> HSV1810 developed for high Ni active material slurries**

# New Kynar® PVDF HSV1810 binder

## Peel strength comparison

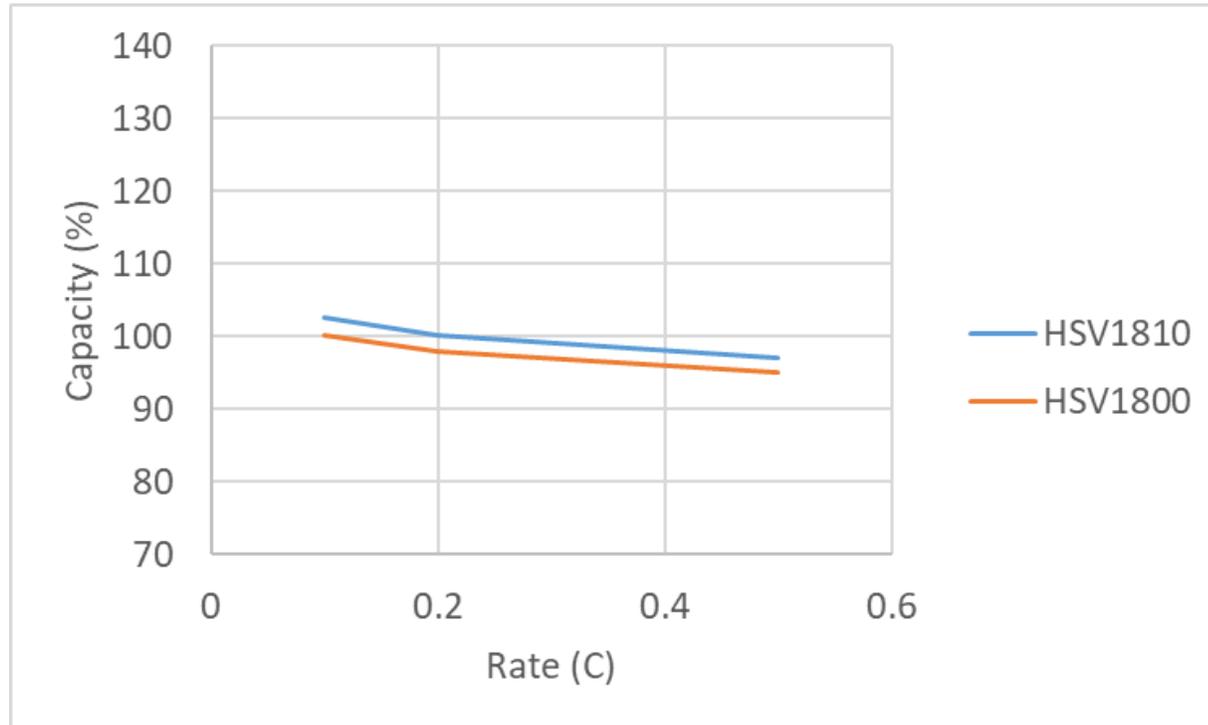


**HSV1810 gives higher peel strength than HSV1800**

# New Kynar® PVDF HSV1810 binder

## Cell performance with NMC622

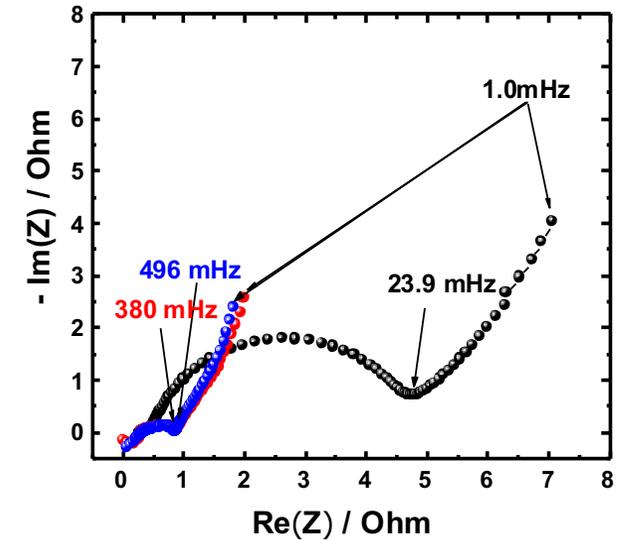
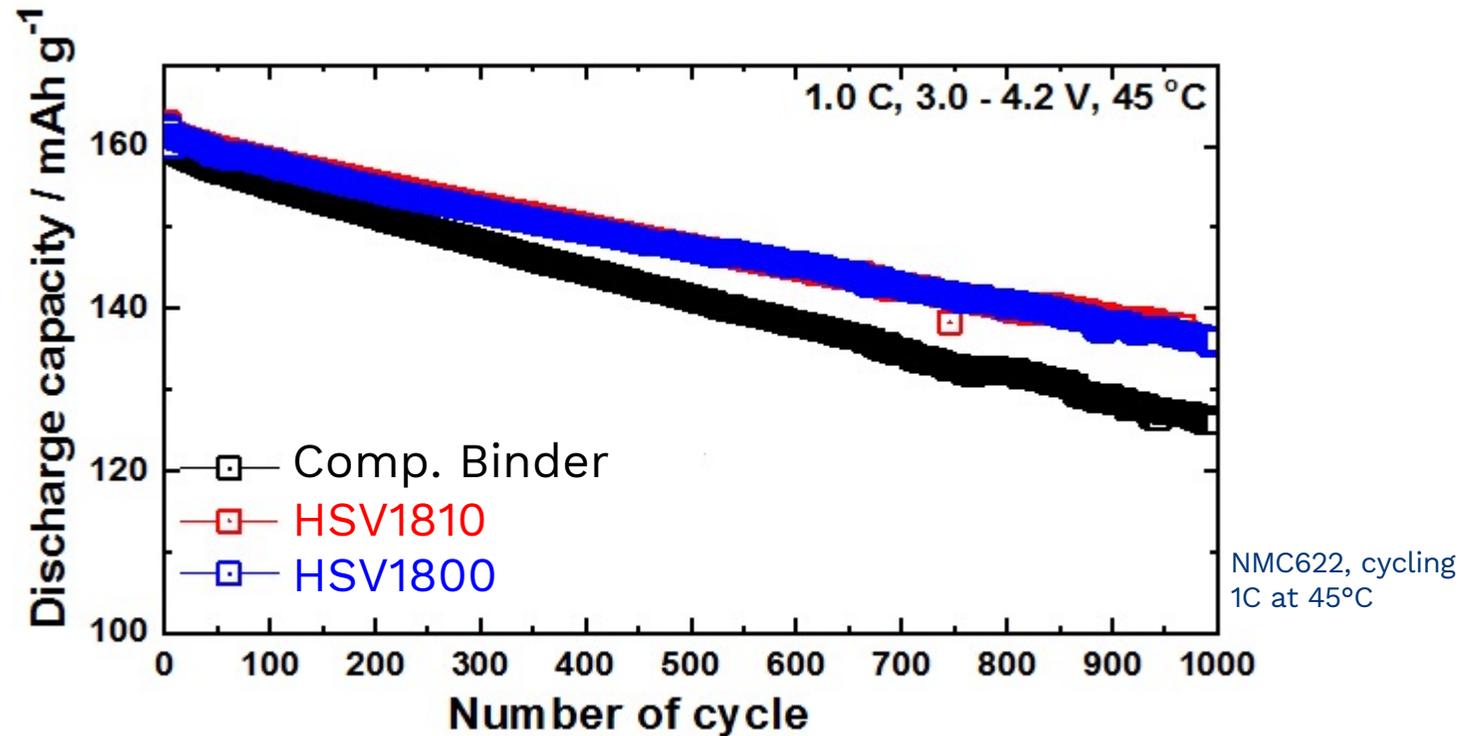
- HSV1810 has higher capacity compared to HSV1800 at different C rates



NMC622(Umicore)/Super P/Binder=97/1.5/1.5  
Full cell results

# New Kynar<sup>®</sup> PVDF HSV1810 binder

## Cycle performance with NMC622



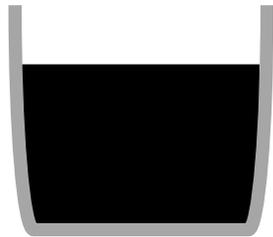
45 °C 500 cycles	$R_{sf}$	$R_{ct}$
Comp. Binder	0.43 Ω	4.75 Ω
HSV1810	0.31 Ω	0.87 Ω
HSV1800	0.37 Ω	0.91 Ω

**HSV1810 showed excellent capacity retention**

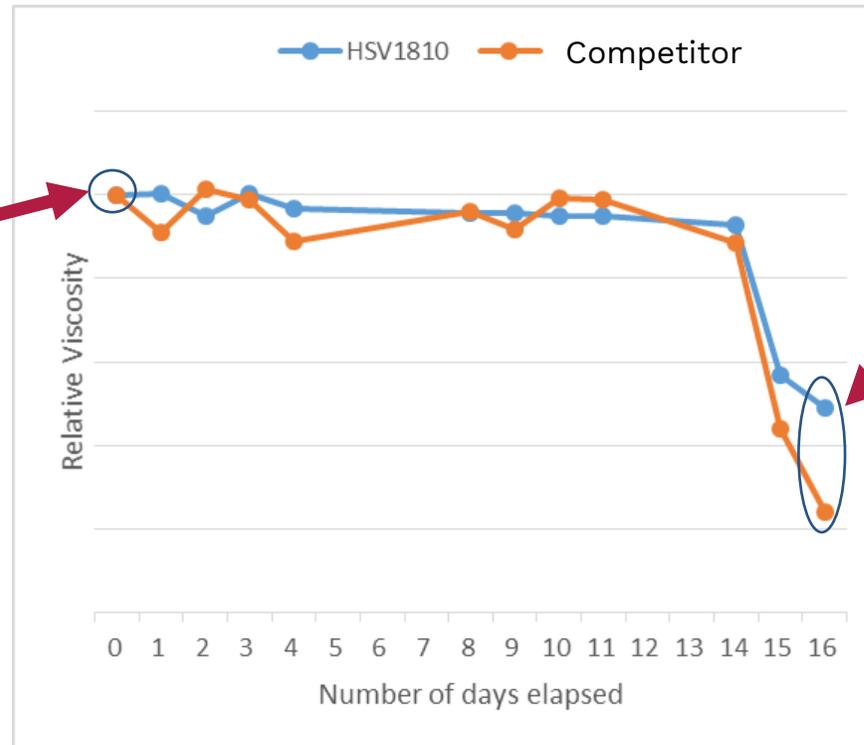
# New Kynar<sup>®</sup> PVDF HSV1810 binder

## Slurry stability with NMC811

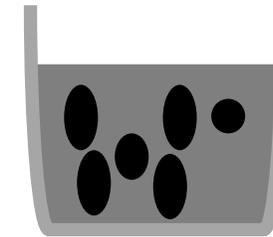
Day 0



Homogeneous  
slurry



Day 16



Gelation/  
coagulation

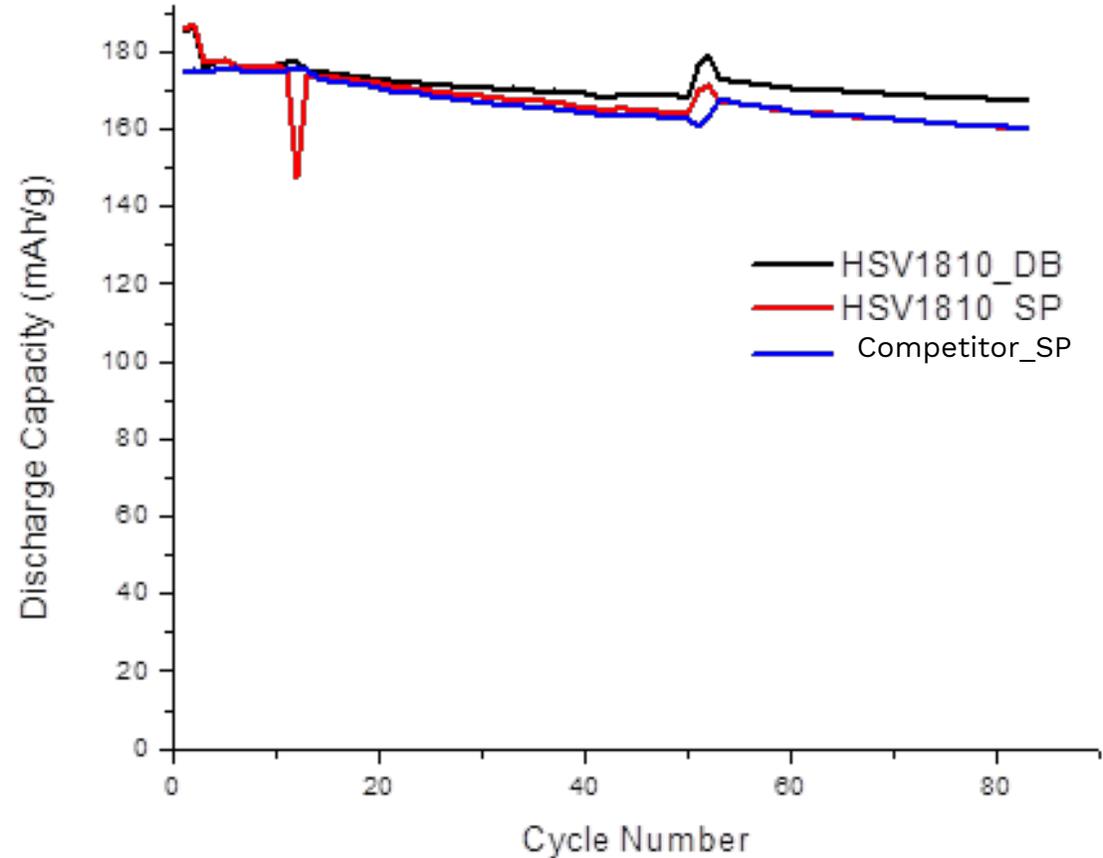


NMC811/CB/Binder=97/1.5/1.5  
r.t. storage

**HSV1810 showed stable viscosity for 14 days at ambient condition**

# New Kynar<sup>®</sup> PVDF HSV1810 binder

## Cycle performance with NMC811



NMC811/CB/Binder=97/1.5/1.5

3-4.2 V

r.t.

Protocol:

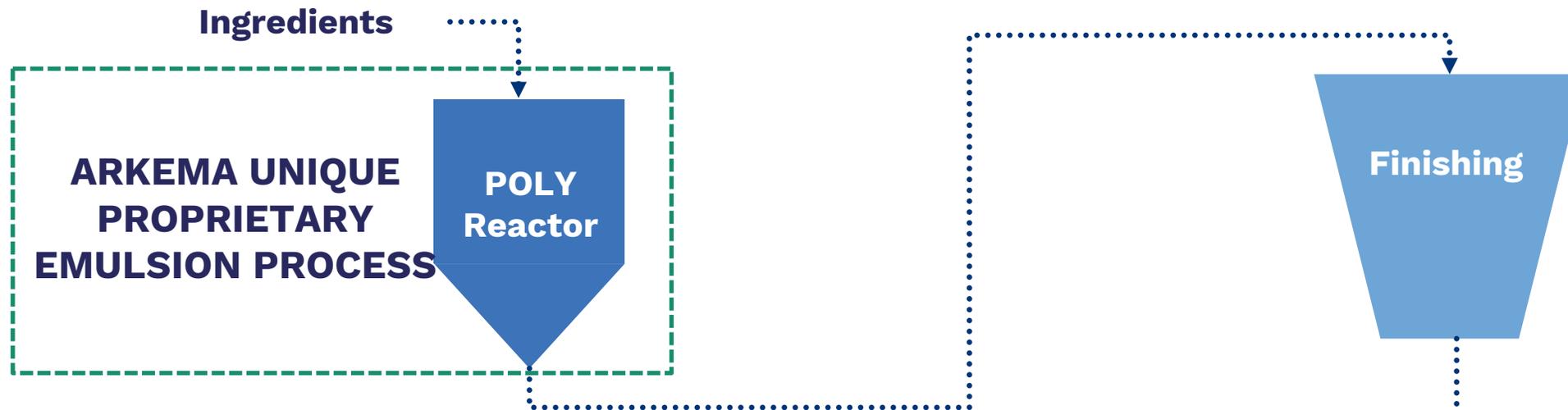
0~2 cycle – 0.1 C

3~50 cycle – 0.5 C

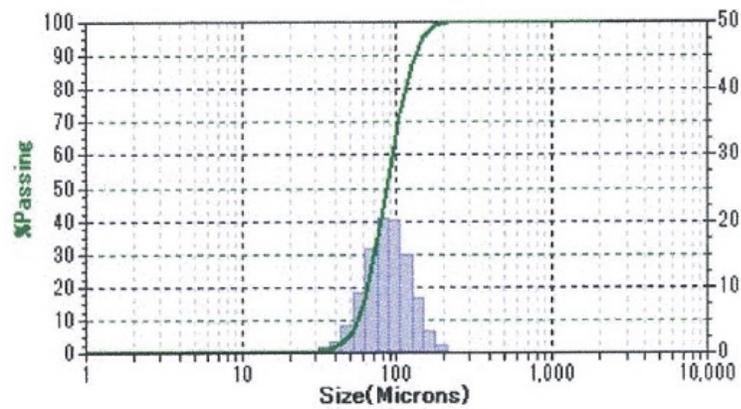
repeat

**HSV1810 showed excellent capacity retention**

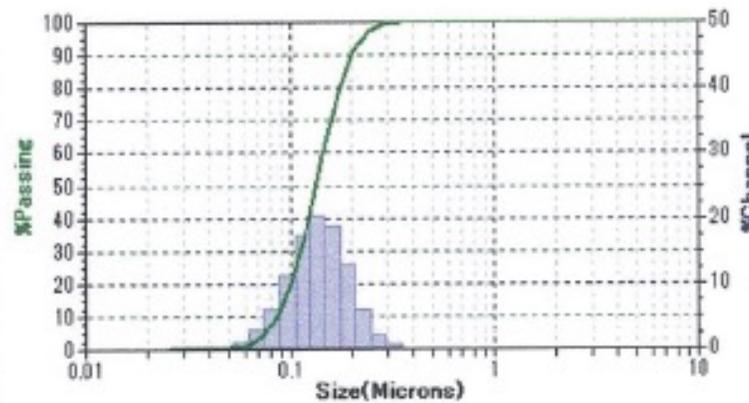
# Specificity of Kynar® PVDF by emulsion



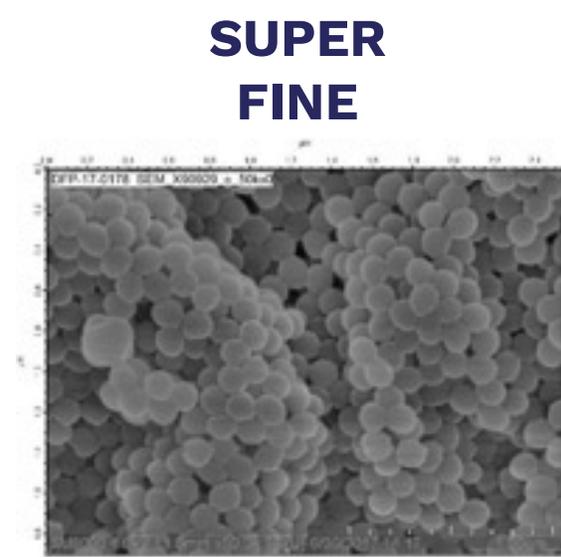
Suspension process



Emulsion process



**Emulsion process gives powder at sub-micron size**

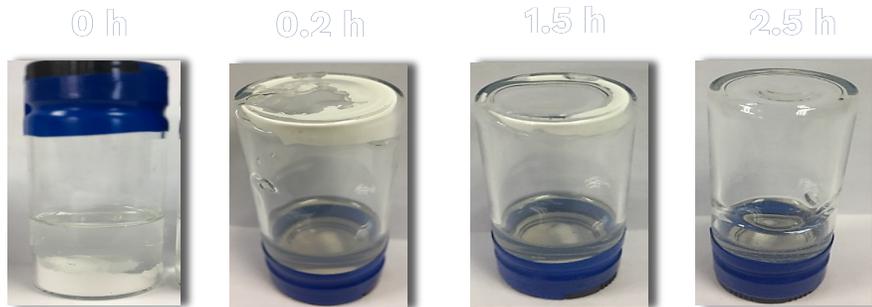


# Processing Consideration

## WET PROCESS

LESS TIME FOR FULL DISSOLUTION

**Kynar®  
HSV1810**

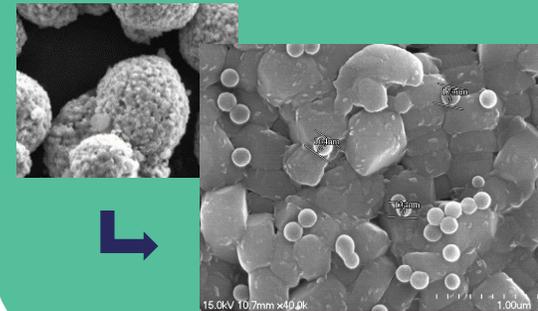


**Suspension  
Resin**



## DRY MIX PROCESS

PERFECT FIT WITH KYNAR®



Homogeneous blend

## SLURRY SOLID CONTENT

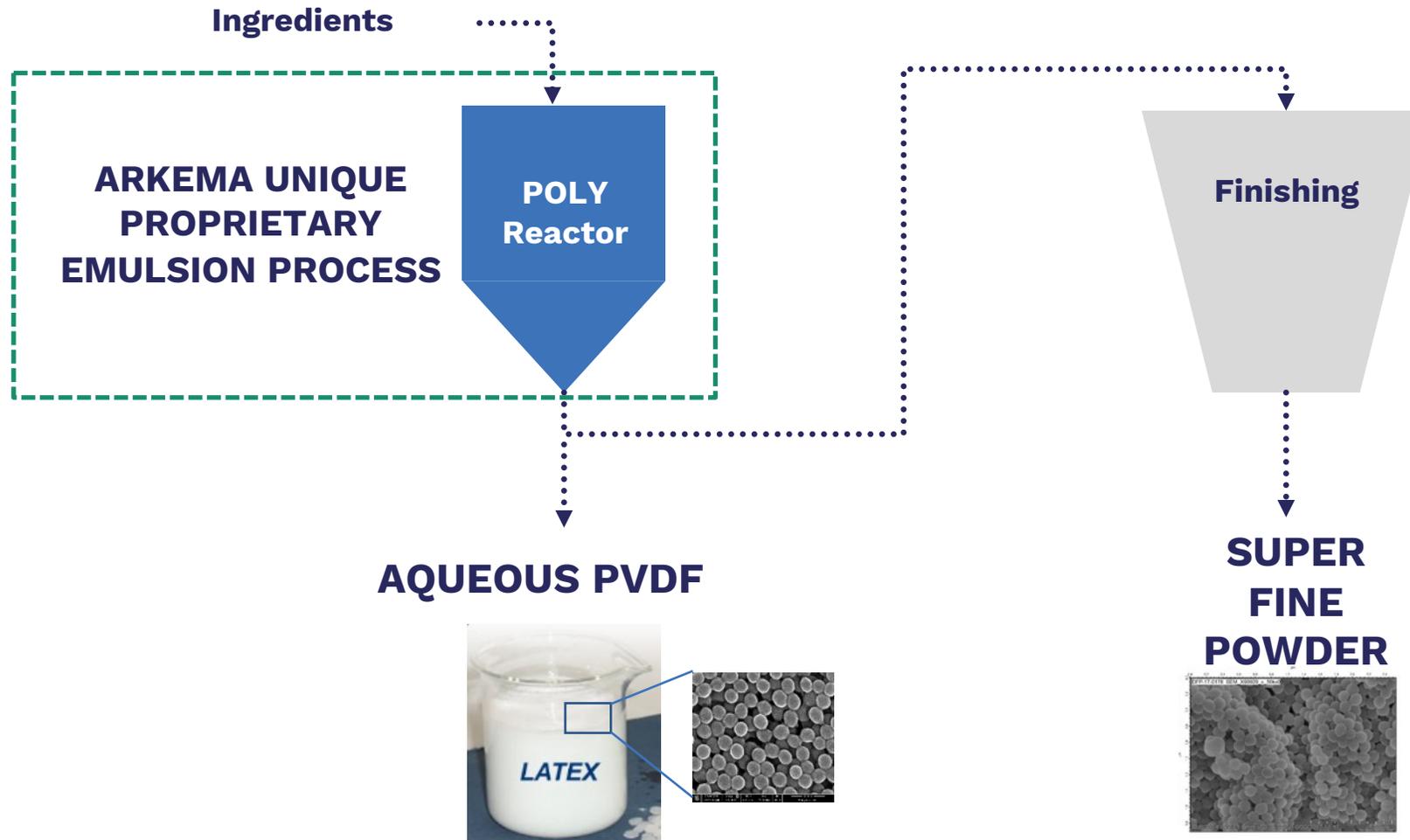
With proper mixing  
conditions with NMC811:

- >80 % solid content
- Excellent adhesion
- Less NMP



Flowing slurry at >80 % solid = less NMP

# Getting rid of NMP – the next challenge

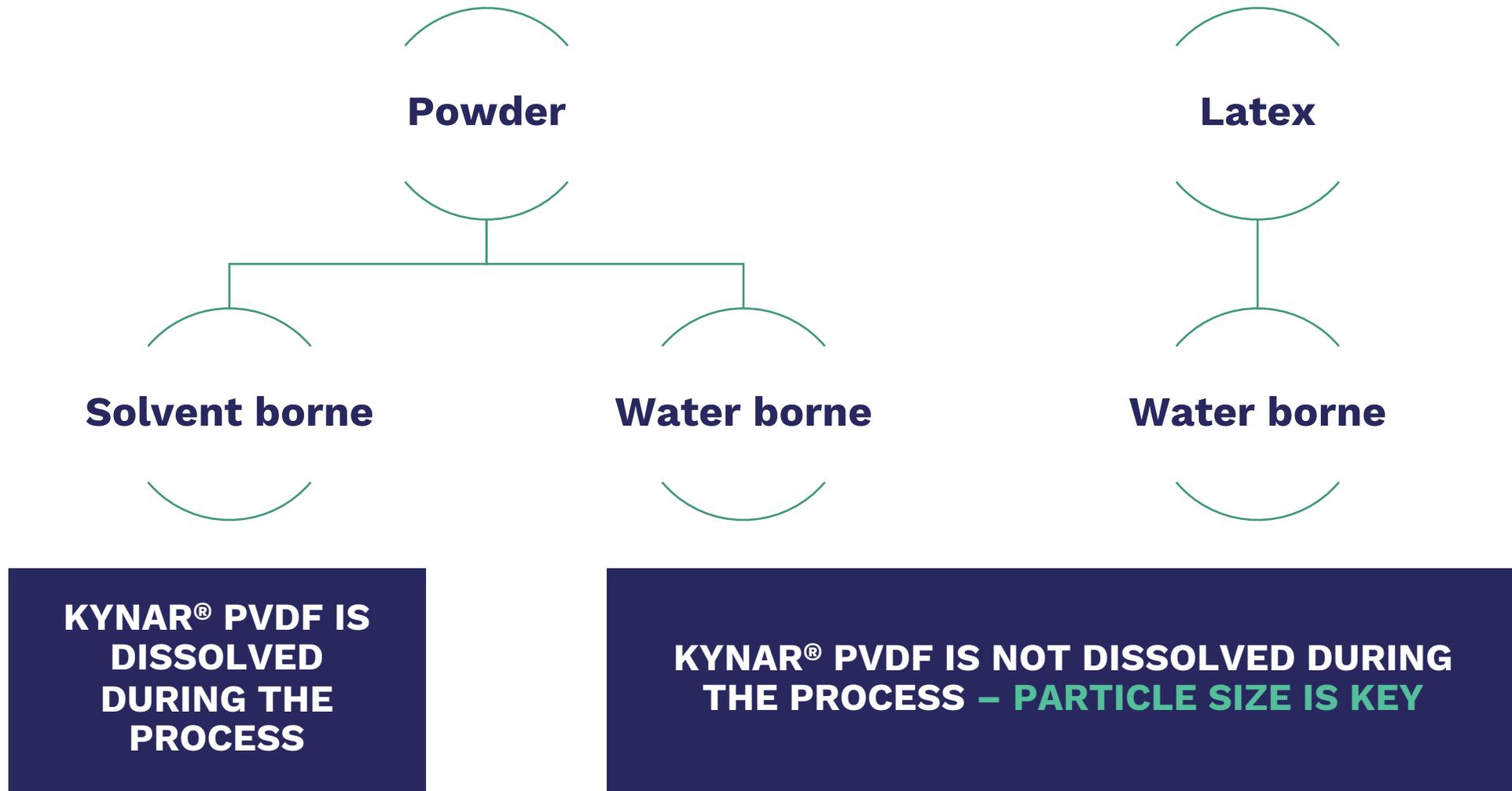


**KYNAR® PVDF STRUCTURE MAKES THE WATERBORNE AND DRY PROCESS POSSIBLE**

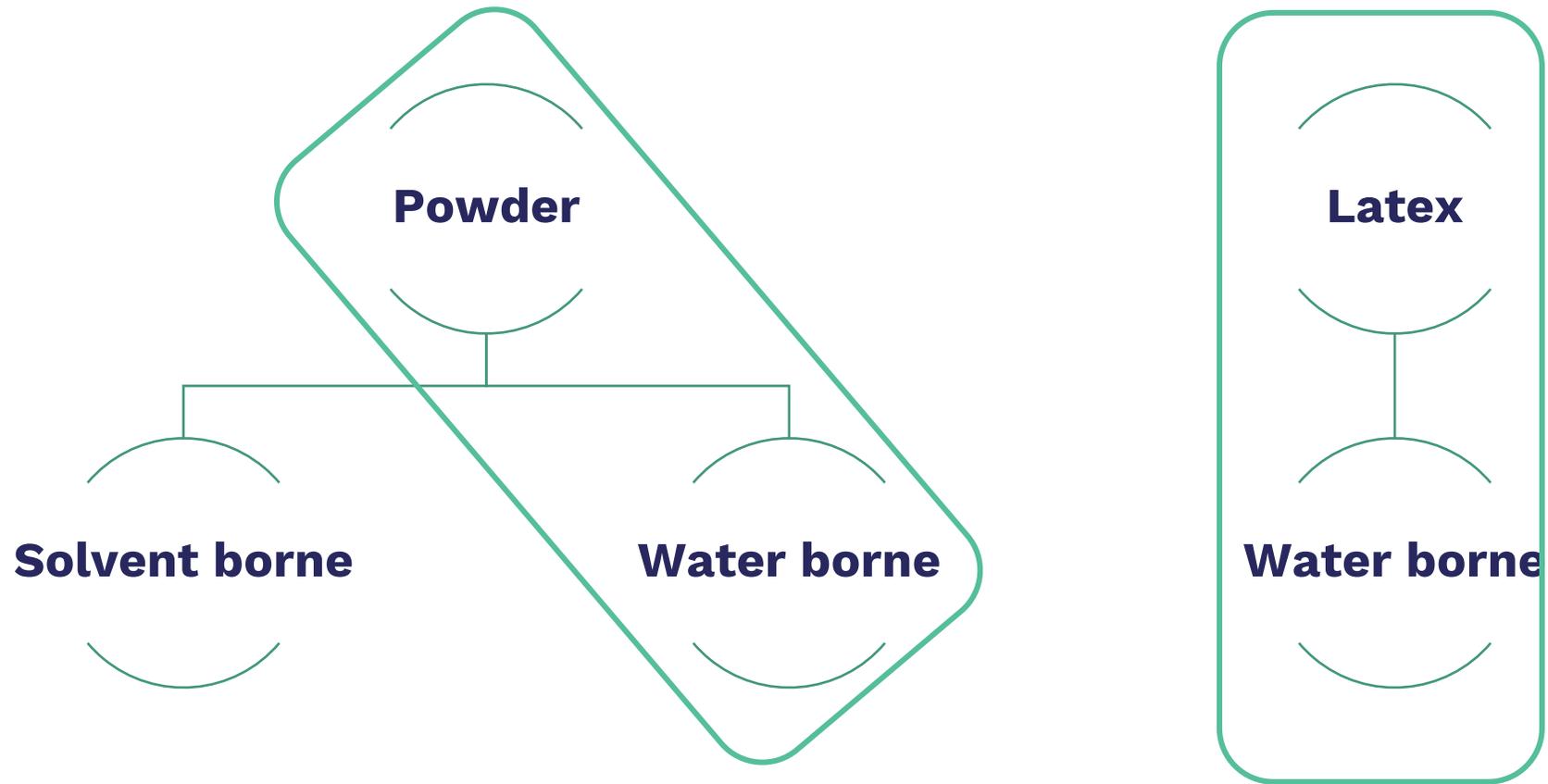
# 3

Focus On Kynar® PVDF  
For Separator Coatings

# Kynar® PVDF solutions for separator coating

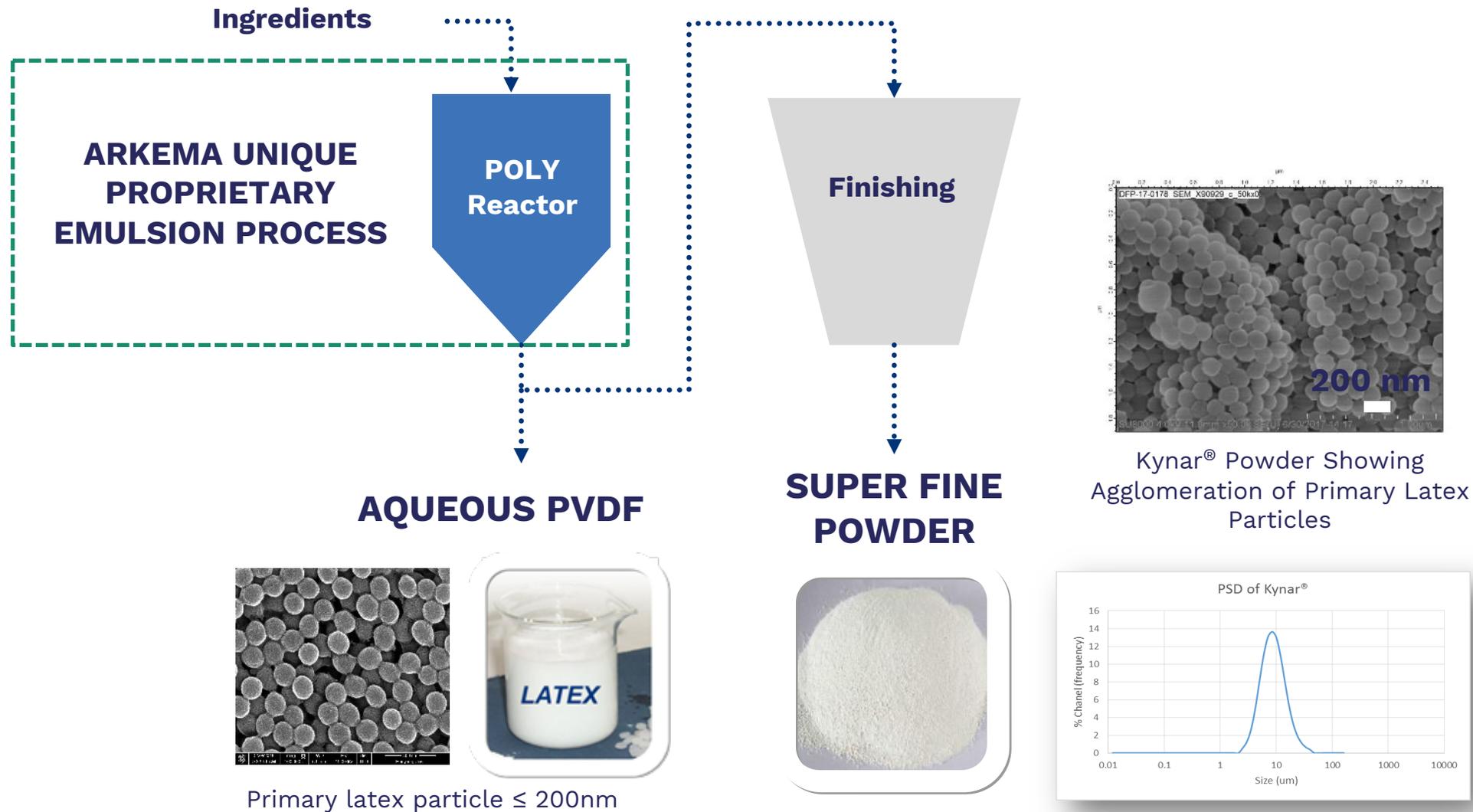


# Kynar® PVDF solutions for separator coating

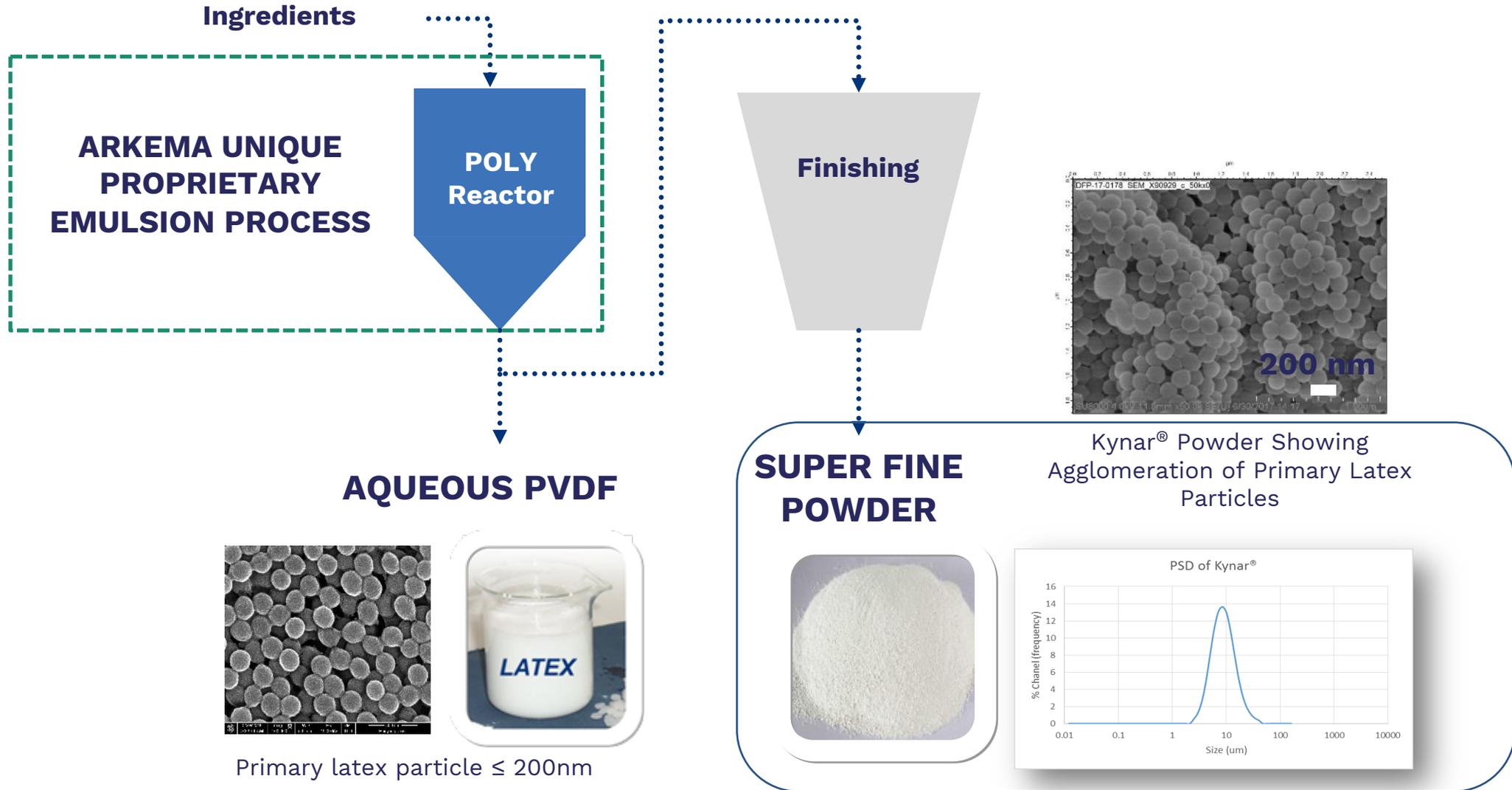


**KYNAR® PVDF FOR WATER BORNE SYSTEM – 2 TECHNICAL OPTIONS**

# Let's take a look at the Specificities of Kynar® PVDF...



# Water-based coating – route 1 with powder



# Redispersion of Kynarflex<sup>®</sup> LBG powder

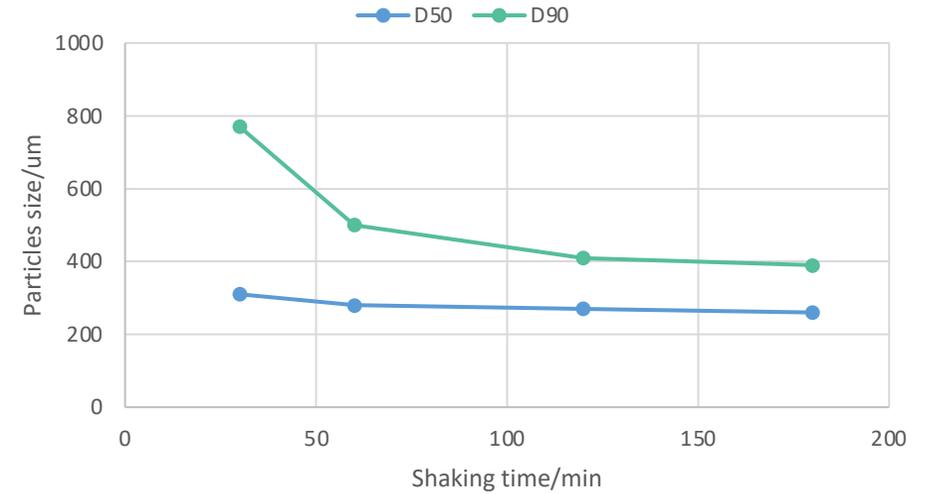


Filling

Contents	Ratio
Kynar <sup>®</sup> LBG	28.5%
W&D Additives (BYK)	1,7% as effective material
Defoamer (BYK)	0,5% as delivery form
Water	69,3%



Shaking

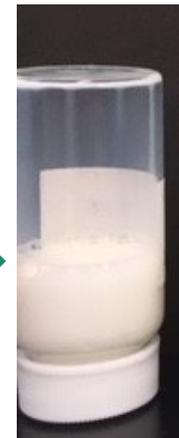


**By formulation and dispersion technology, Kynarflex<sup>®</sup> LBG powder can be redispersed into water**

- To achieve desired particles size distribution.
- To achieve very stable dispersion

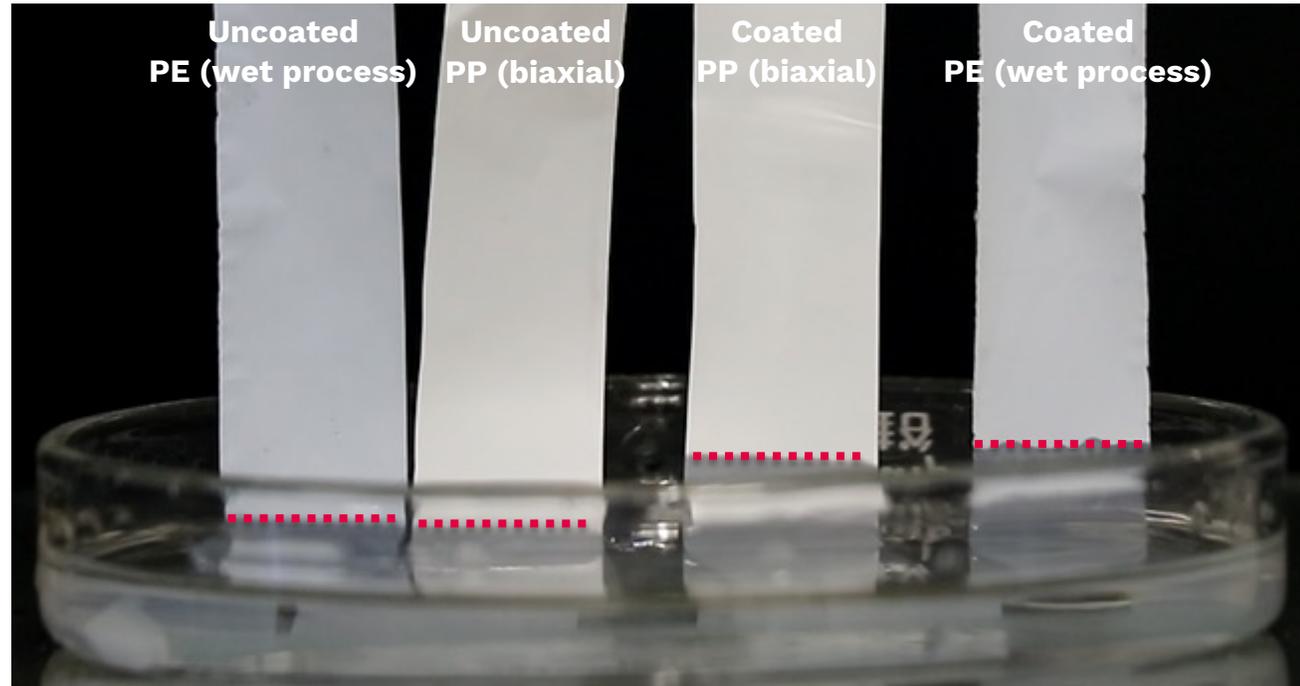
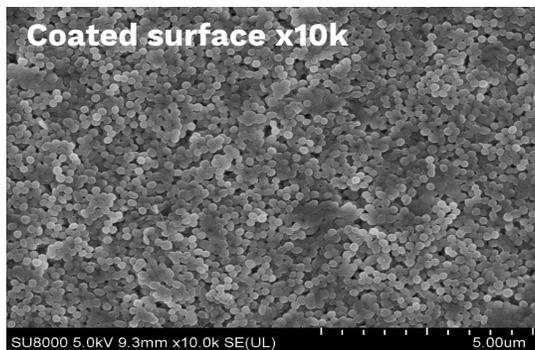
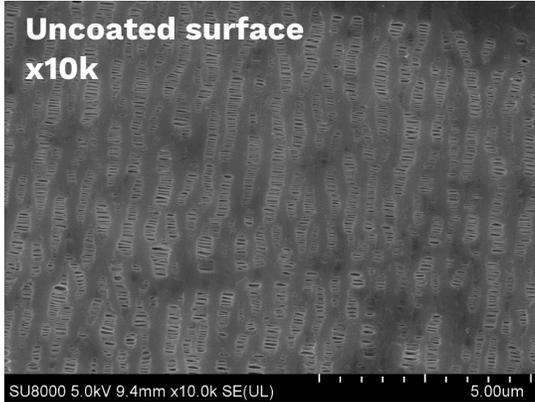


After 3 days storage



# Kynarflex<sup>®</sup>LBG coated separator – electrolyte wetting

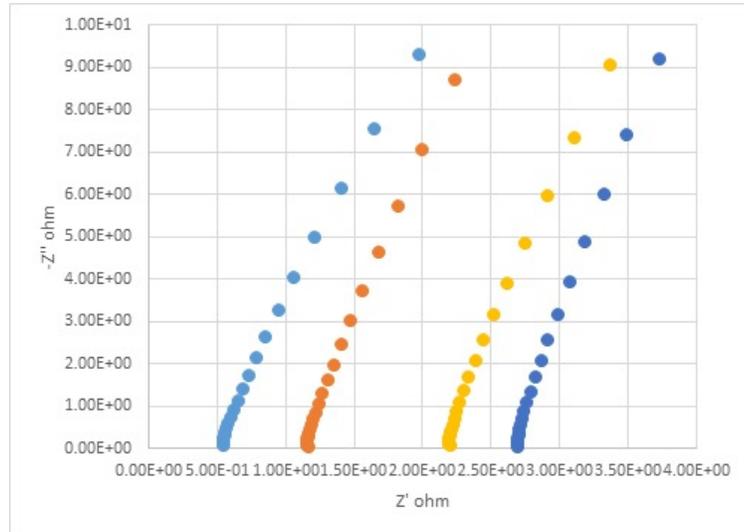
Results from a WB formulation based on Kynarflex<sup>®</sup> LBG



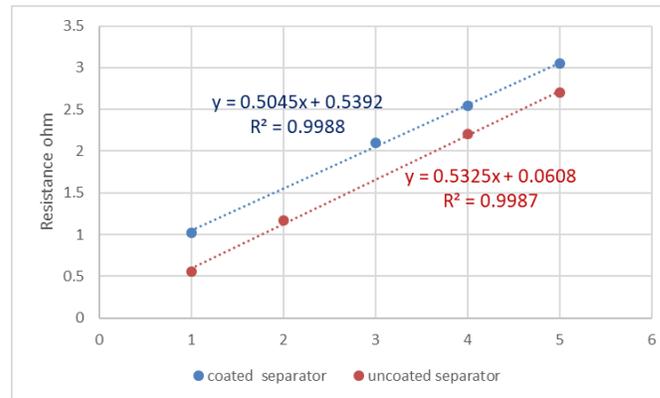
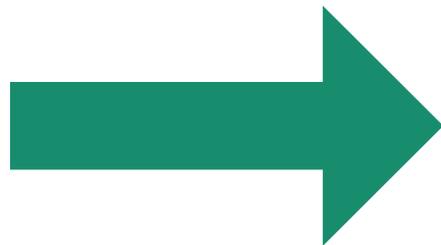
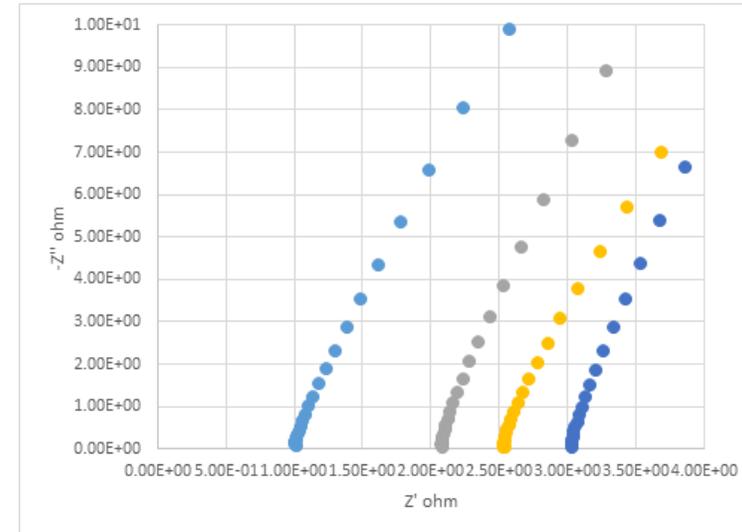
**PVDF coated separator show better wetting performance which can absorb the liquid electrolyte.**

# Kynarflex<sup>®</sup>LBG coated separator – ionic conductivity

**Uncoated Separator**

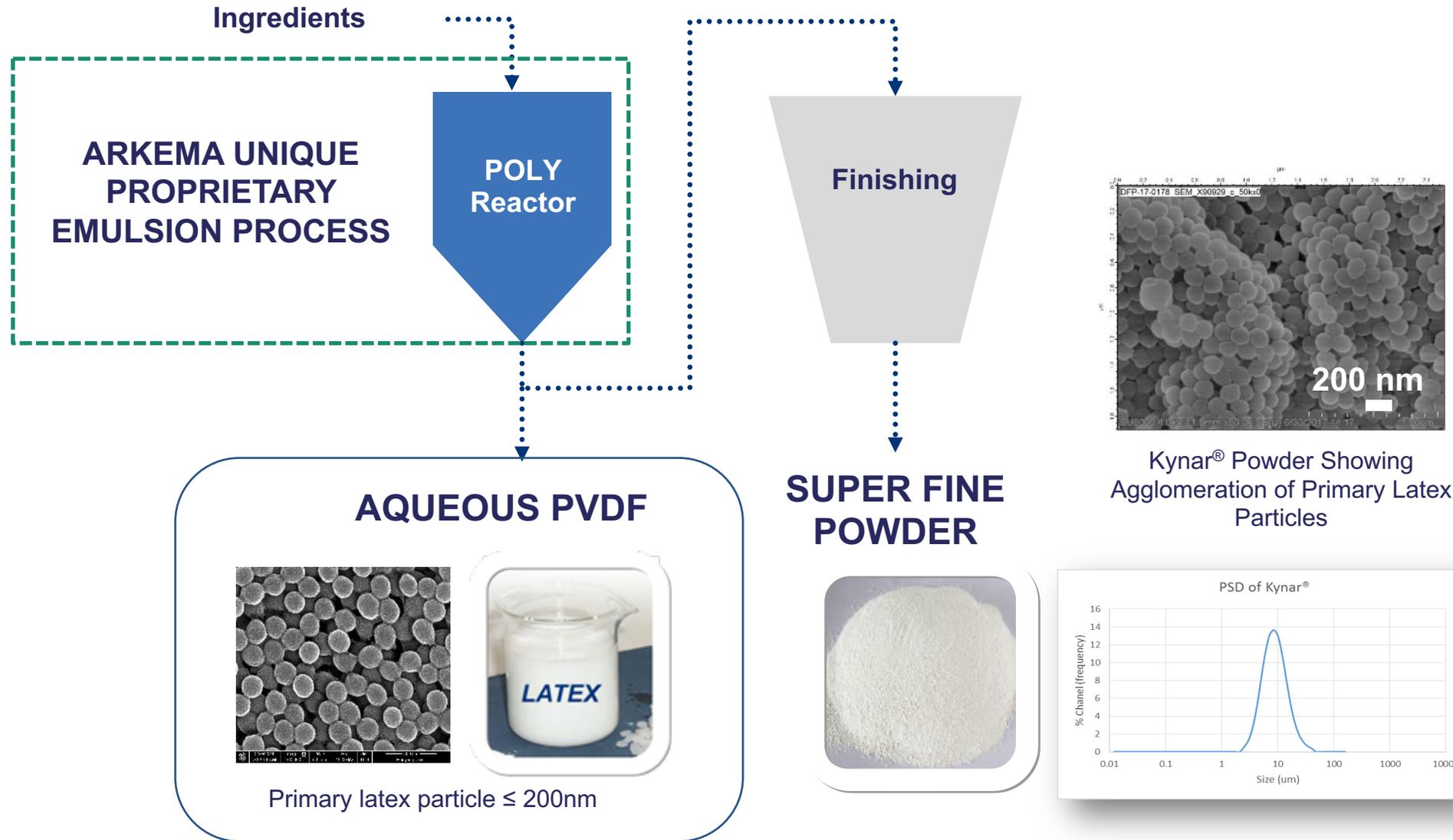


**Kynarflex<sup>®</sup> LBG Coated Separator**

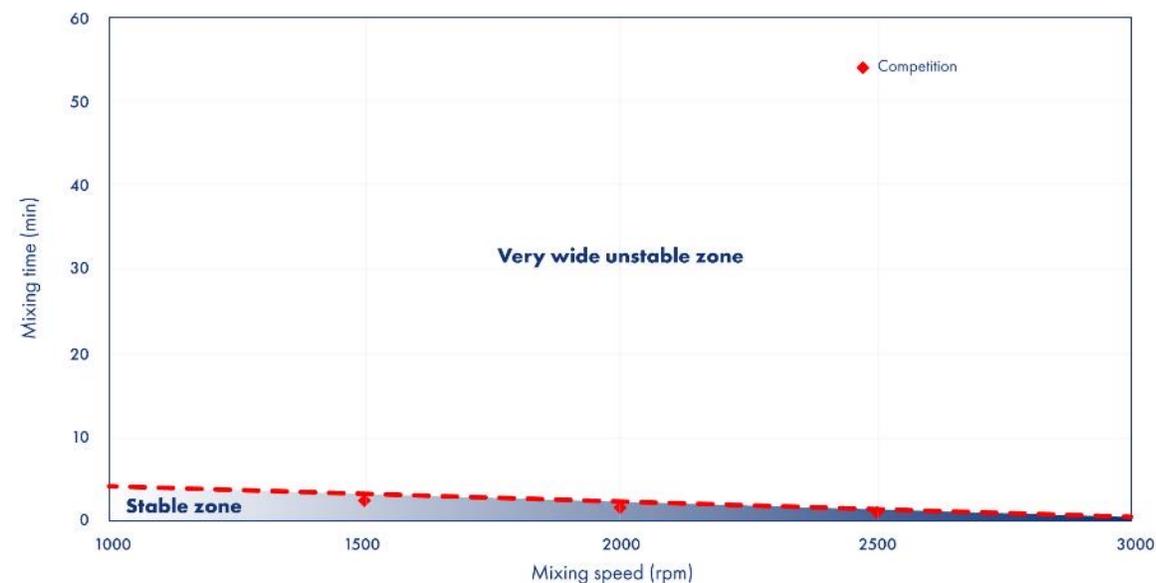
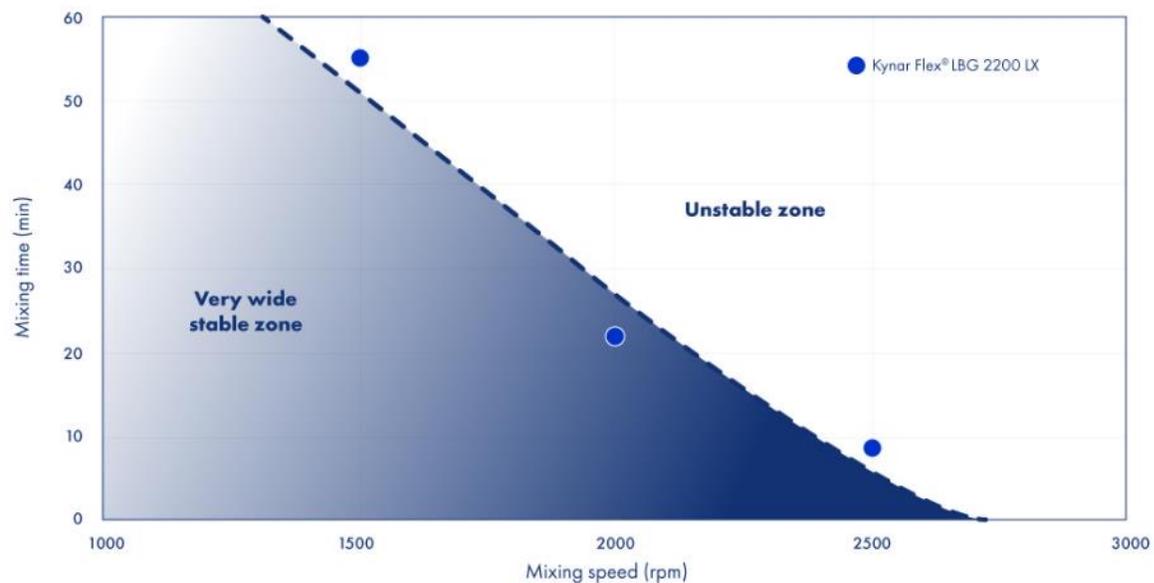


**Resistance of coated separator is slightly lower than uncoated separator**  
**Coated separator: 0.50 ohm**  
**Uncoated separator: 0.53 ohm**

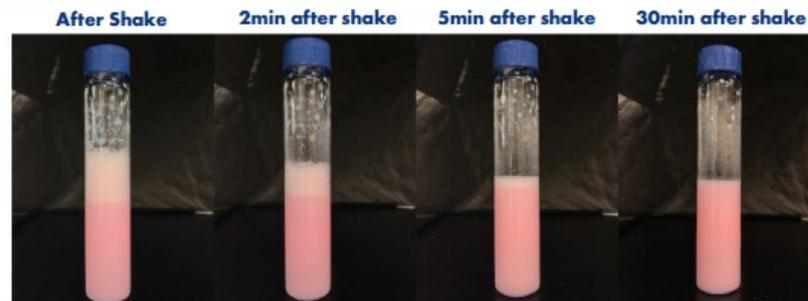
# Water-based coating – route 2 with latex



# Outstanding stability of aqueous kynar® PVDF « LX technology »

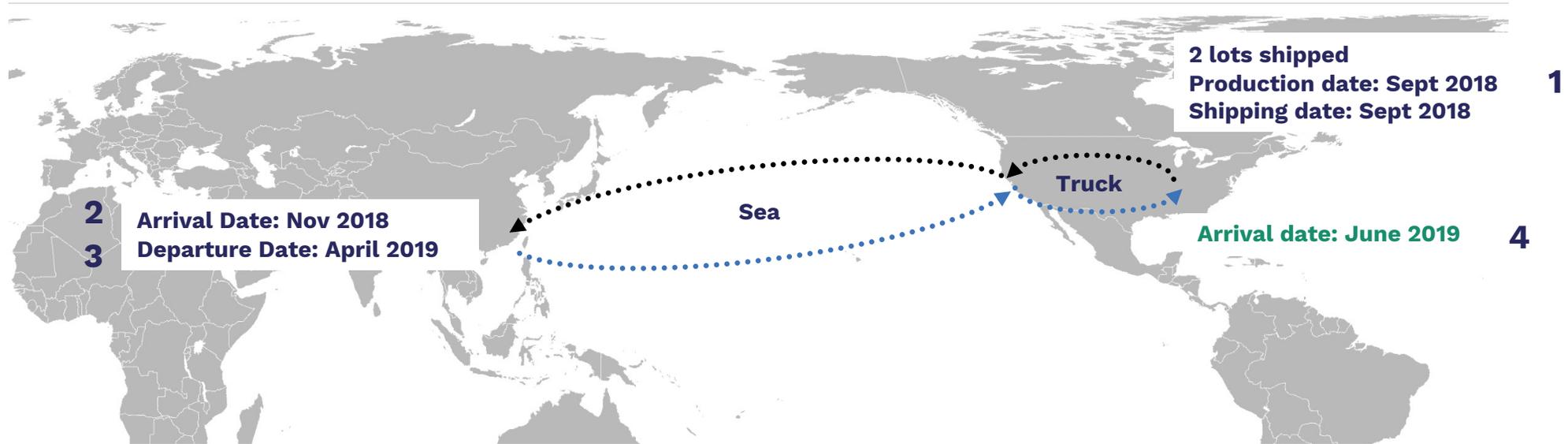


## Low foaming after shaking



✚ **The colored 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.

# Shipping stress test - let's play ping-pong with Kynarflex® LBG2200LX



- The two open top drums gave a good visual check on latex condition.
- Both drums had no foam or coagulum floating on top.
- Time to coagulates remains in line with fresh production and at excellent level
- No changes in particle size

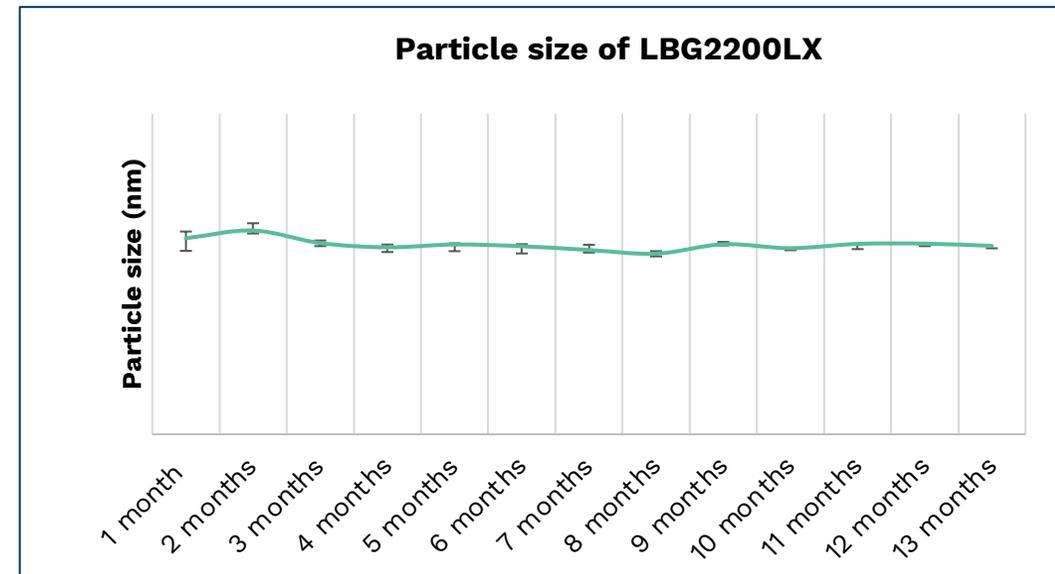
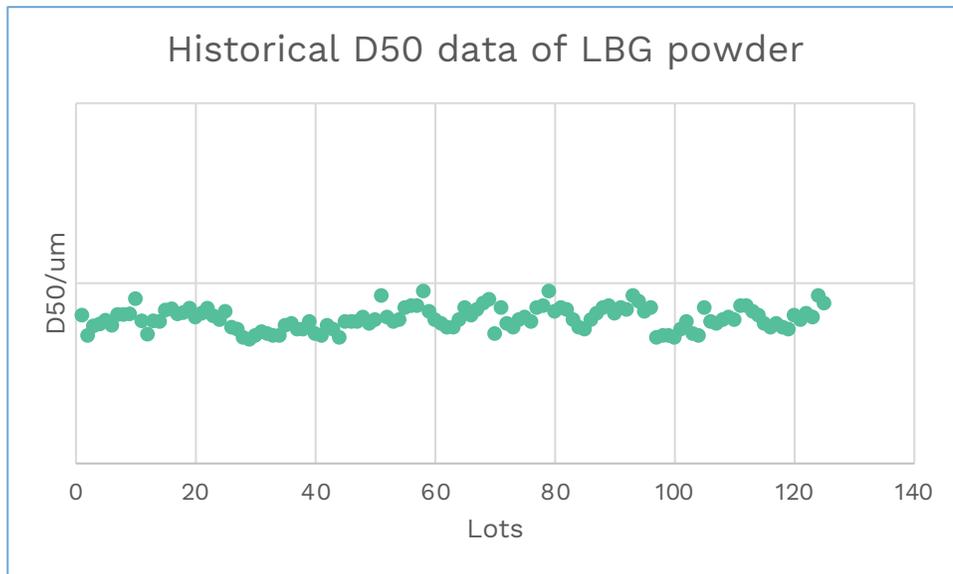
**SHIPPING STRESS TEST PASSED**



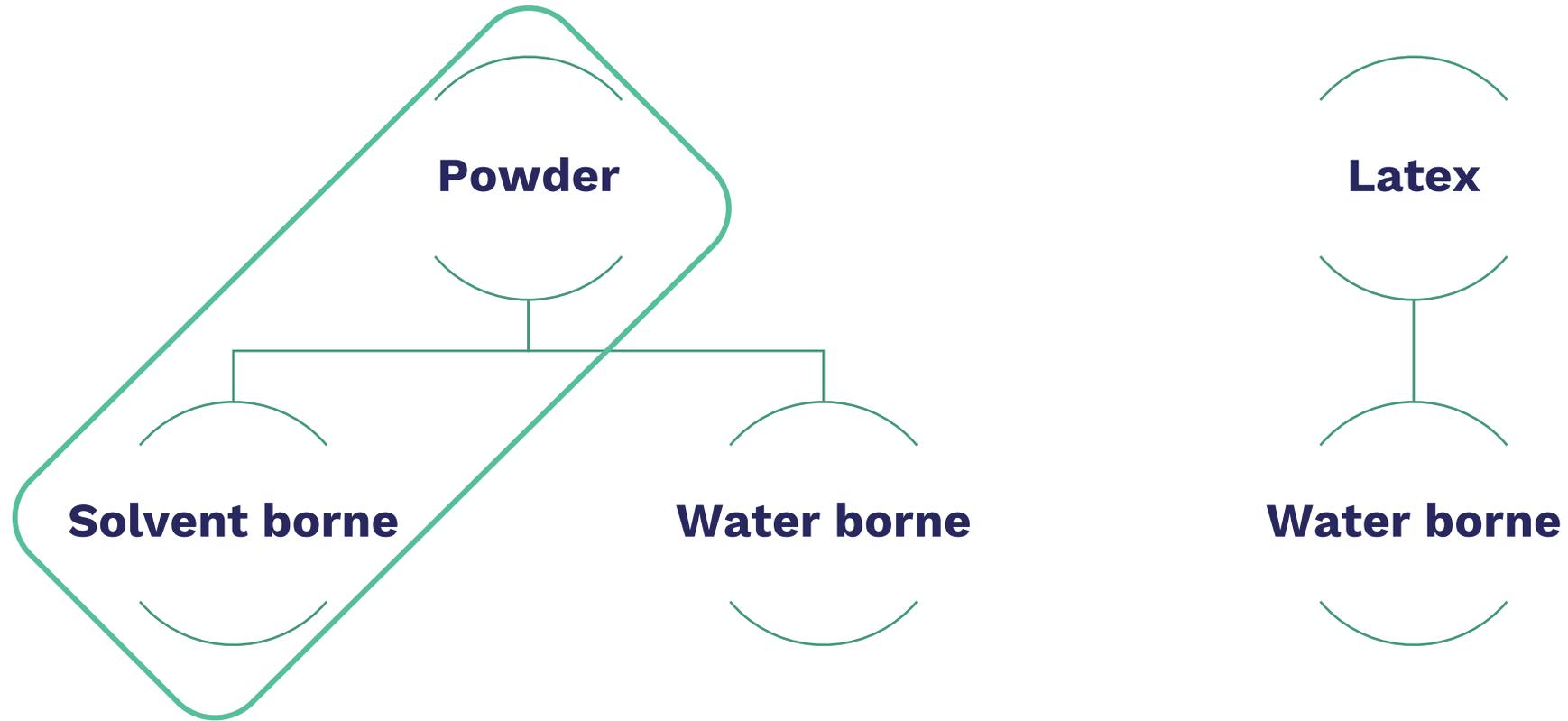
# Kynar® PVDF - product consistency for water-based coating

Outstanding track record of particle size control in both Dry Powder and Latex

Best in class shelf life for Kynar® PVDF latex.



# Kynar<sup>®</sup> PVDF solutions for separator coating



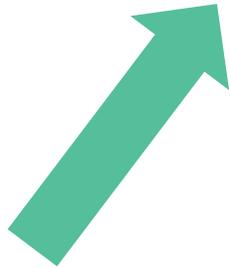
**KYNAR<sup>®</sup> POWDER FOR SOLVENT BORNE SYSTEM**

# New Kynar<sup>®</sup> PVDF grade

## Next Generation

● **Kynar Flex<sup>®</sup> LBG 8200** (functionalized)

**Outstanding Dry & Wet Adhesion**  
**Product designed with higher MW**

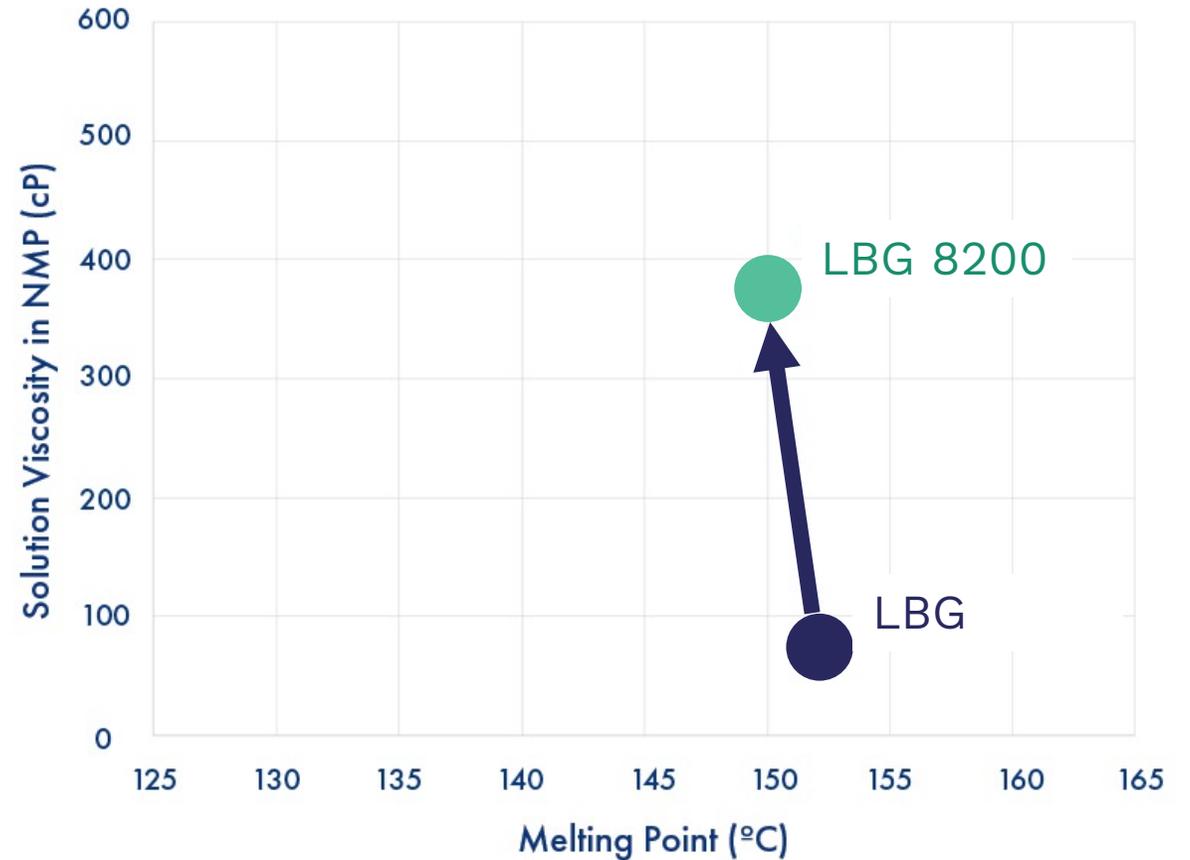


## Current Generation

● **Kynar Flex<sup>®</sup> LBG**

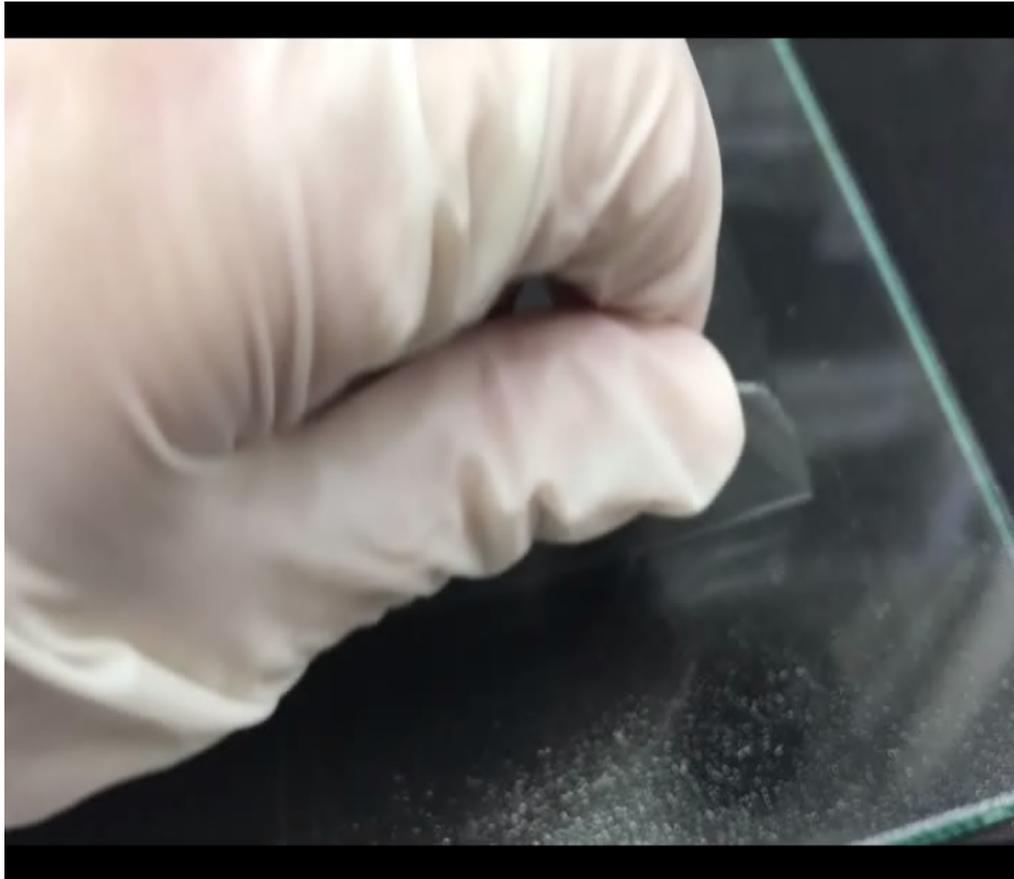
**The market reference**  
**Excellent balance of properties**

Product Portfolio Extension

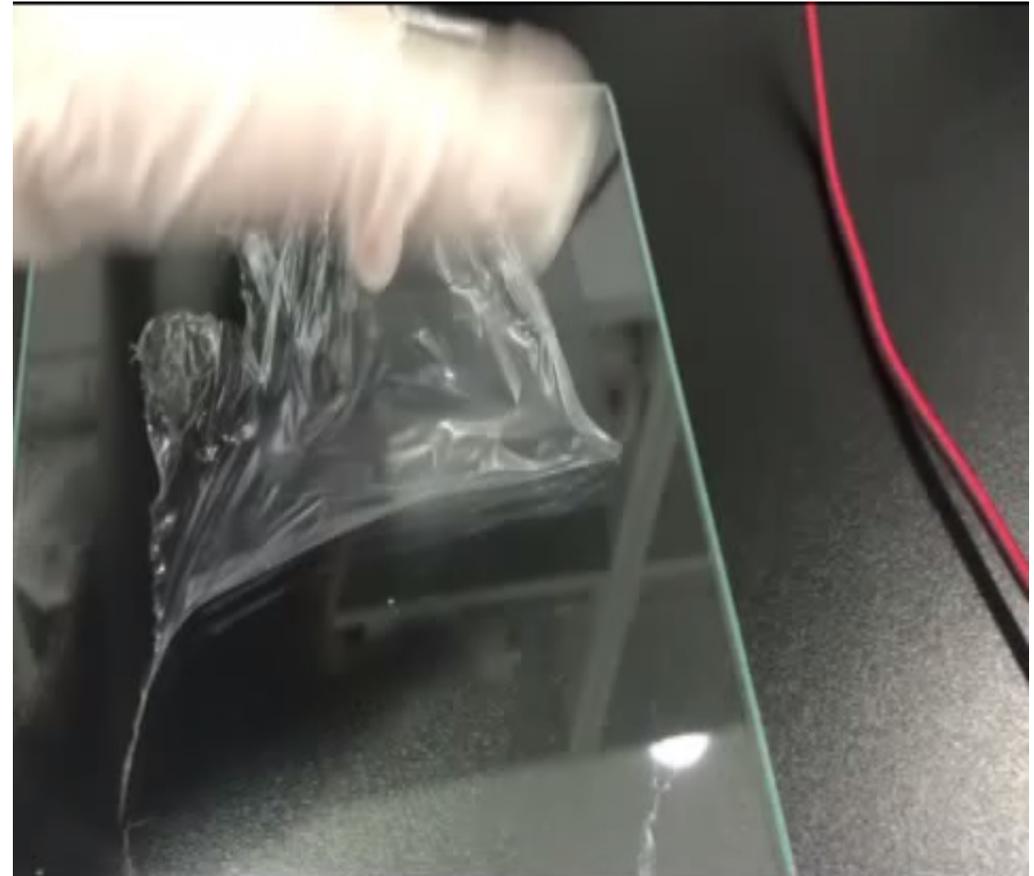


# Kynarflex® functional

**KYNARFLEX®**



**FUNCTIONAL KYNARFLEX®**



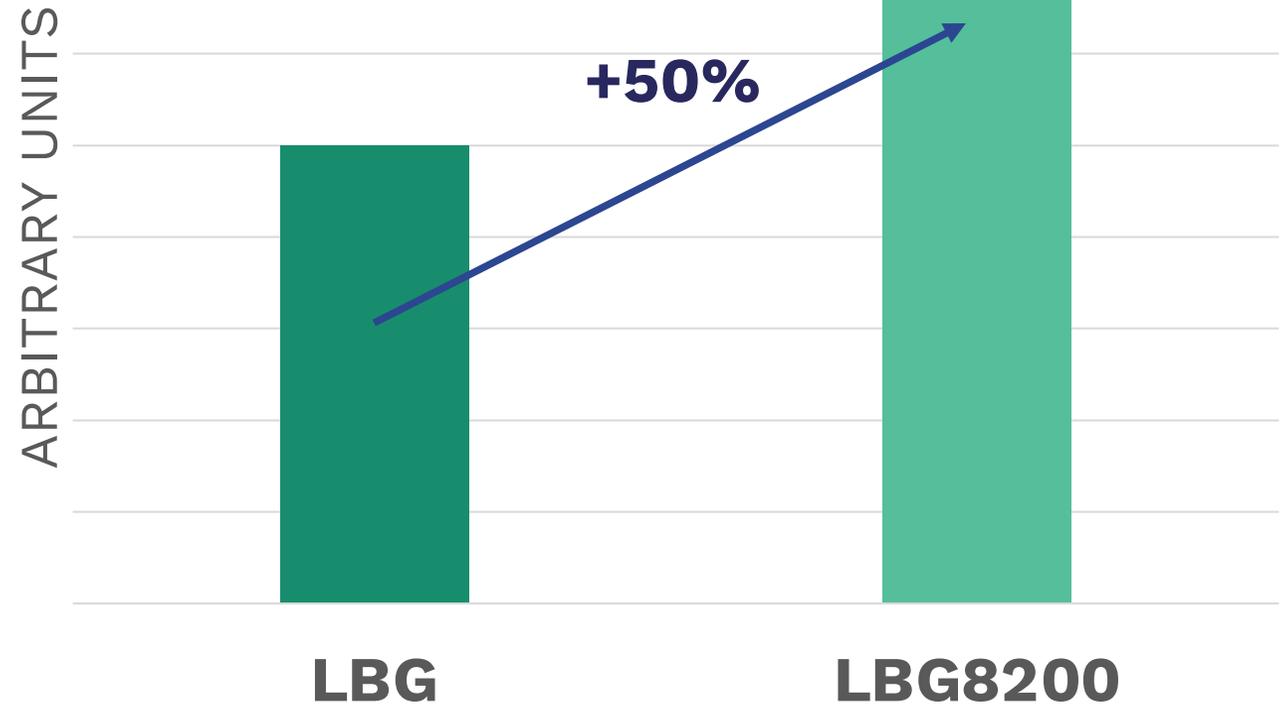
# Kynarflex<sup>®</sup> LBG8200 - improves adhesion

## ➤ **DRY ADHESION TO ELECTRODE**

- Better Processing
- Better Handling
- Less defects

## ➤ **WET ADHESION TO ELECTRODE**

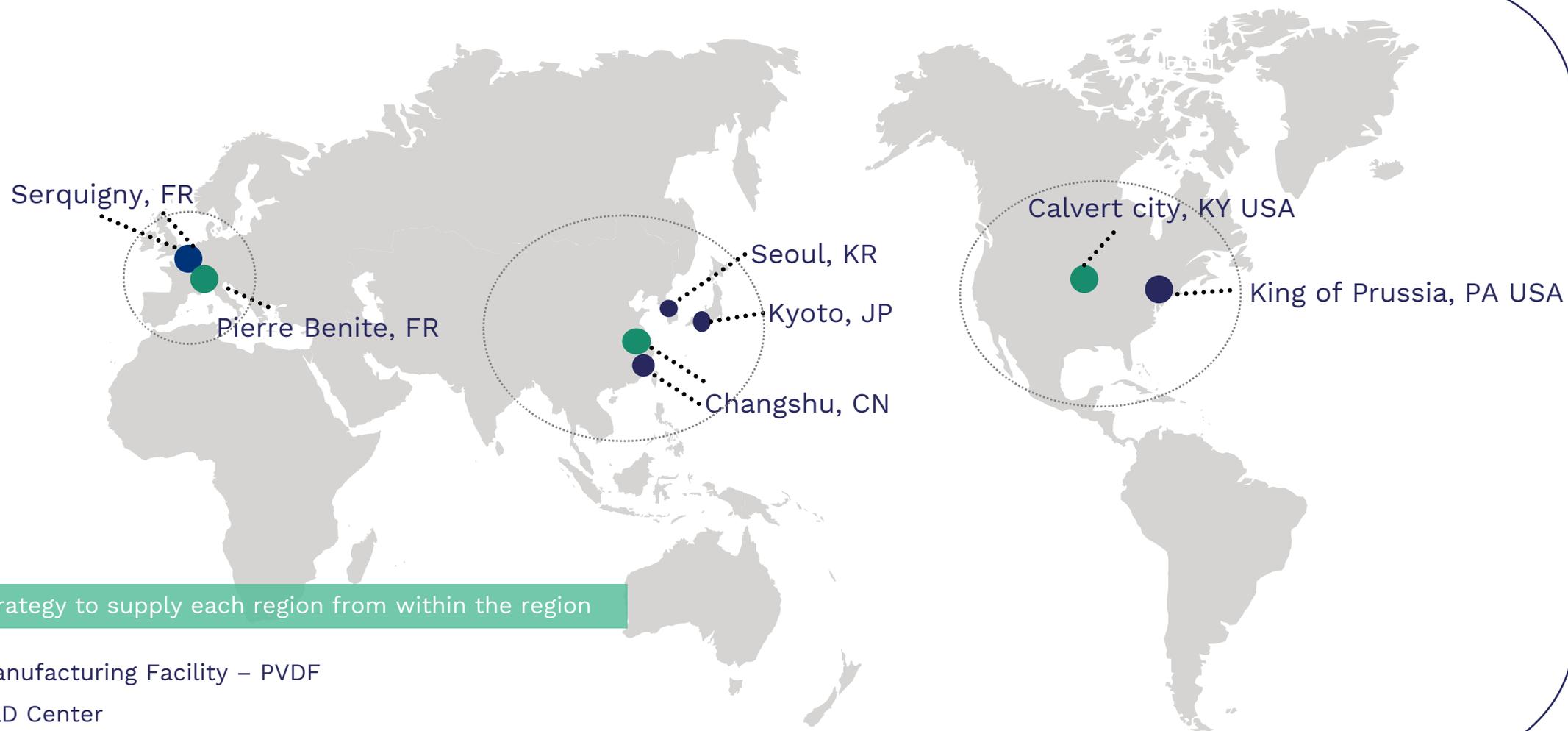
- To improve cell performance

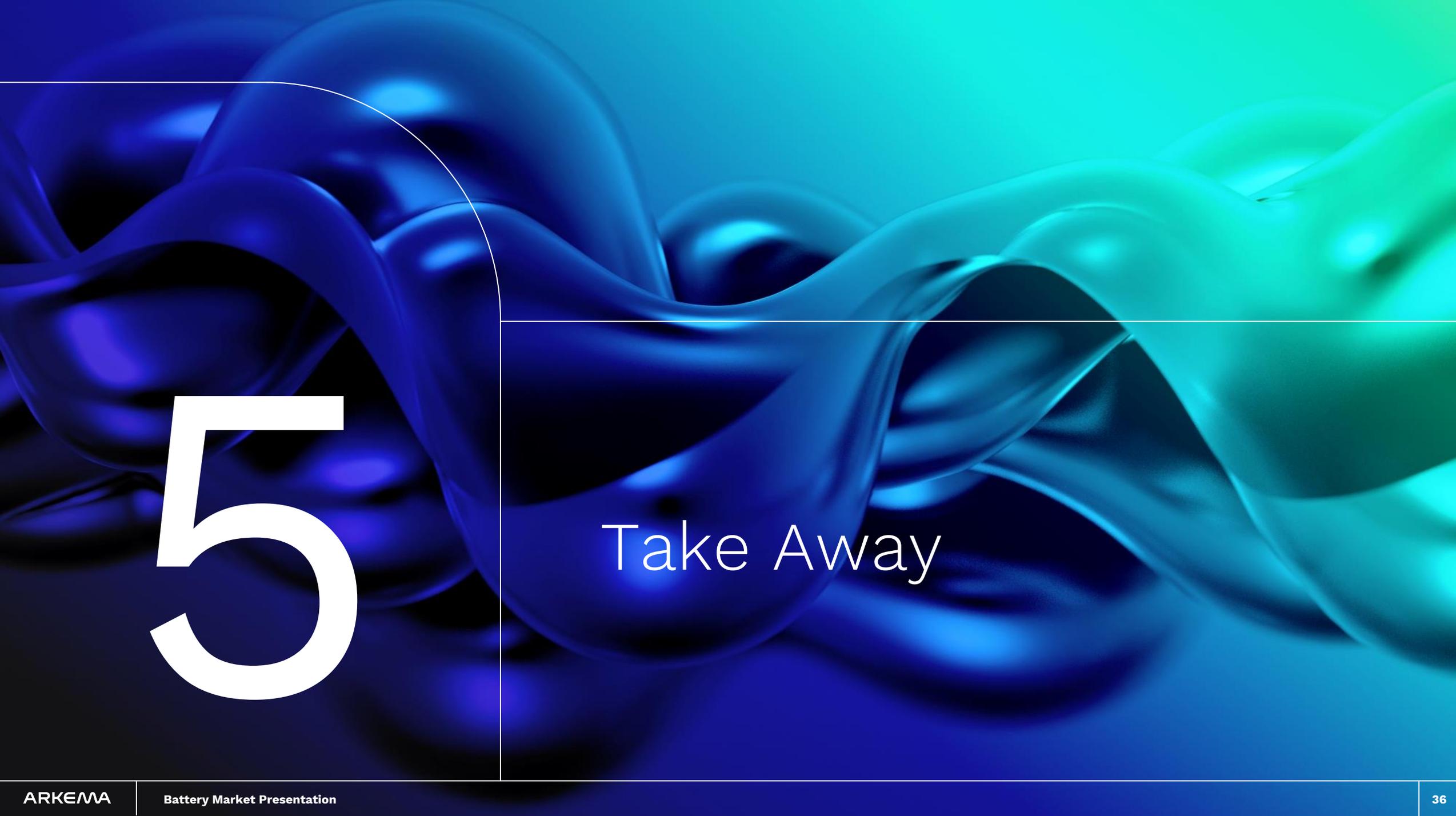


# 4

## Supply Security

# Kynar® PVDF – a global presence with one process





5

Take Away

# Takeaway

## **KYNAR® PVDF FOR BINDERS**

- **Arkema provides wide range of PVDF homopolymer and copolymers**
- **Kynar® HSV900 remains the market reference for LFP cathodes**
- **Kynar® HSV1800 designed to bring more benefit especially to LFP and LCO systems**
- **Kynar® HSV1810 is developed for high Ni active material systems**
- **Kynar® PVDF made by emulsion polymerization provides benefit in electrode production**

## **KYNAR® PVDF FOR SEPARATORS**

**Kynar® PVDF - the largest PVDF used in the world for separator coating**

**Kynar® PVDF – the broadest portfolio in the market**

- **Powder / Latex**
- **Broad range of copolymers**

**Kynar® PVDF – Serving the region from the region**

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