



LITHIUM ION BATTERY SEPARATORS

FREUDENBERG
PERFORMANCE MATERIALS

 **FREUDENBERG**
INNOVATING TOGETHER

FREUDENBERG – THE SAFETY SEPARATOR

SUPERIOR QUALITY FOR HIGH DEMANDS

The separator is a critical component of a Lithium Ion cell. It provides a barrier between anode and cathode while enabling Lithium Ion transport between the electrodes.

Freudenberg Performance Materials has been producing separators and other components for primary and secondary batteries for over 40 years. Freudenberg separators provide safety in consumer, industrial, automotive, and aviation applications. Our supply chain is well established and we are able to provide local tech support worldwide. Our focus is to meet the highest demands of our customers.

The next generation of high power and high energy Lithium Ion cells introducing new high voltage electrodes into the market pose new challenges in terms of safety and reliability especially

to electrochemical inactive materials, e.g. separators. Thermal and mechanical separator properties directly influence device safety on the cell level. Ceramic separators by Freudenberg Performance Materials provide excellent thermal and mechanical durability, offering a major safety benefit for batteries compared to conventional membrane based separator technologies.

The Freudenberg Lithium Ion ceramic separator technology is the ideal choice for applications in harsh environments and unusual cell designs enabling elevated working temperatures or highly corrosive electrolytes. Combining extraordinary cell performance in fast-charging applications with enhanced cycle life, Freudenberg Lithium Ion battery separators make your cell ready for energy storage and electromobility.

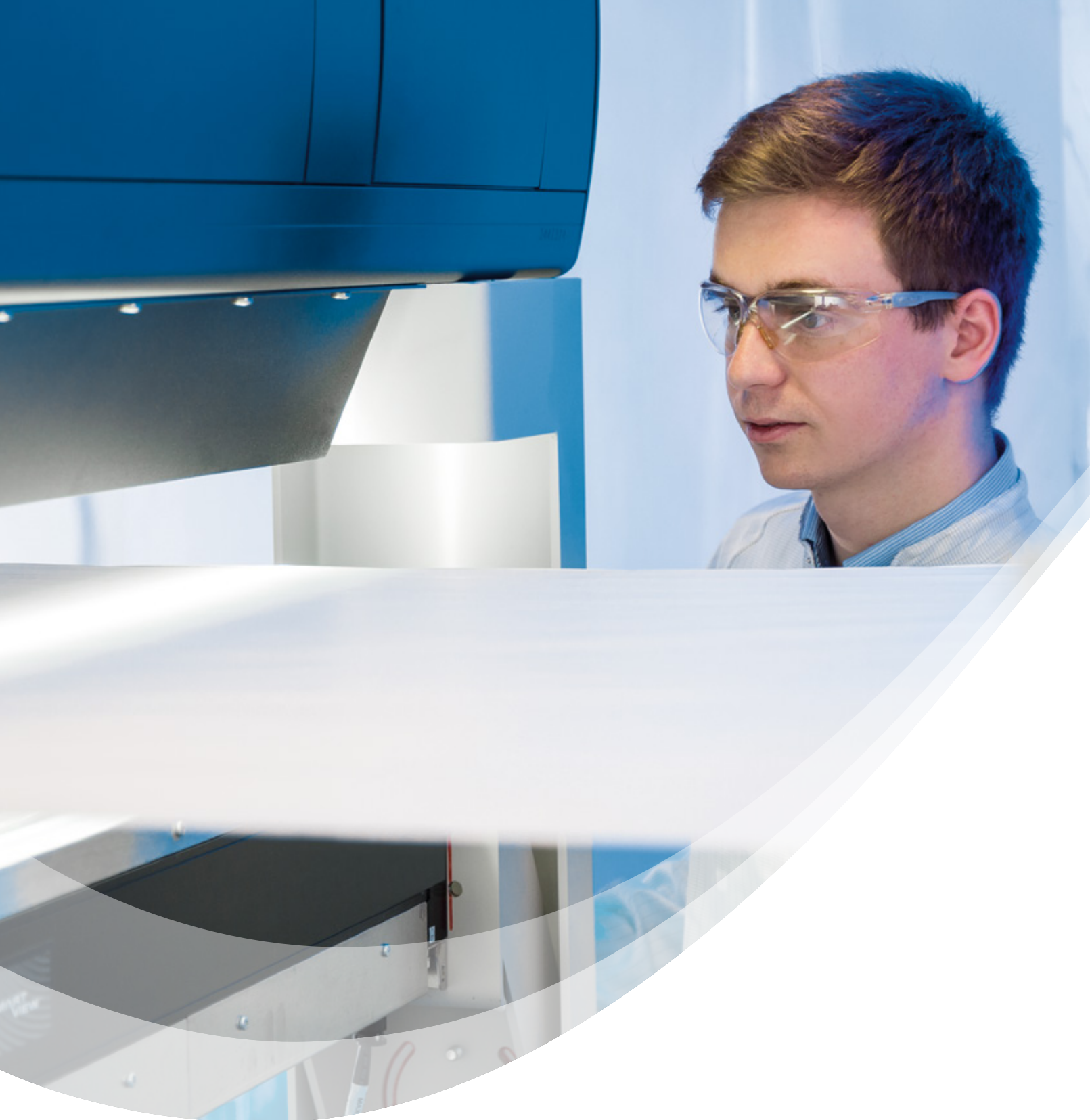


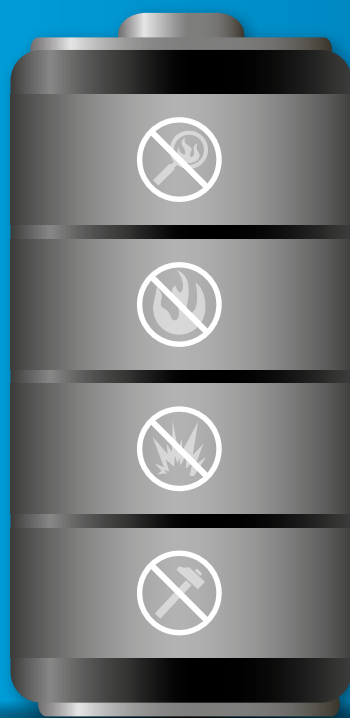
FREUDENBERG PERFORMANCE MATERIALS

Freudenberg Performance Materials is a leading global manufacturer of innovative technical textiles offering differentiated value propositions to a broad range of markets and applications such as Apparel, Automotive, Building Materials, Hygiene, Medical, Shoe and Leathergoods as well as Specialties. Our aim is to be a pioneer in the technological development of innovative materials and solutions as well as new production processes. We work together with our international customers in diverse teams to create tailor-made solutions that bring decisive added value to their operations. The company has 25 manufacturing

sites in 14 countries and more than 3,800 associates. Freudenberg Performance Materials attaches great importance to social and ecological responsibility.

As part of the global Freudenberg Group with 40,000 employees in more than 30 market segments, Freudenberg Performance Materials benefits from a unique network of expertise. Every day, we exploit the richly diverse business structures of Freudenberg to support interdisciplinary learning, pool knowledge and optimize production processes.





No localized heat up

No large scale heat up

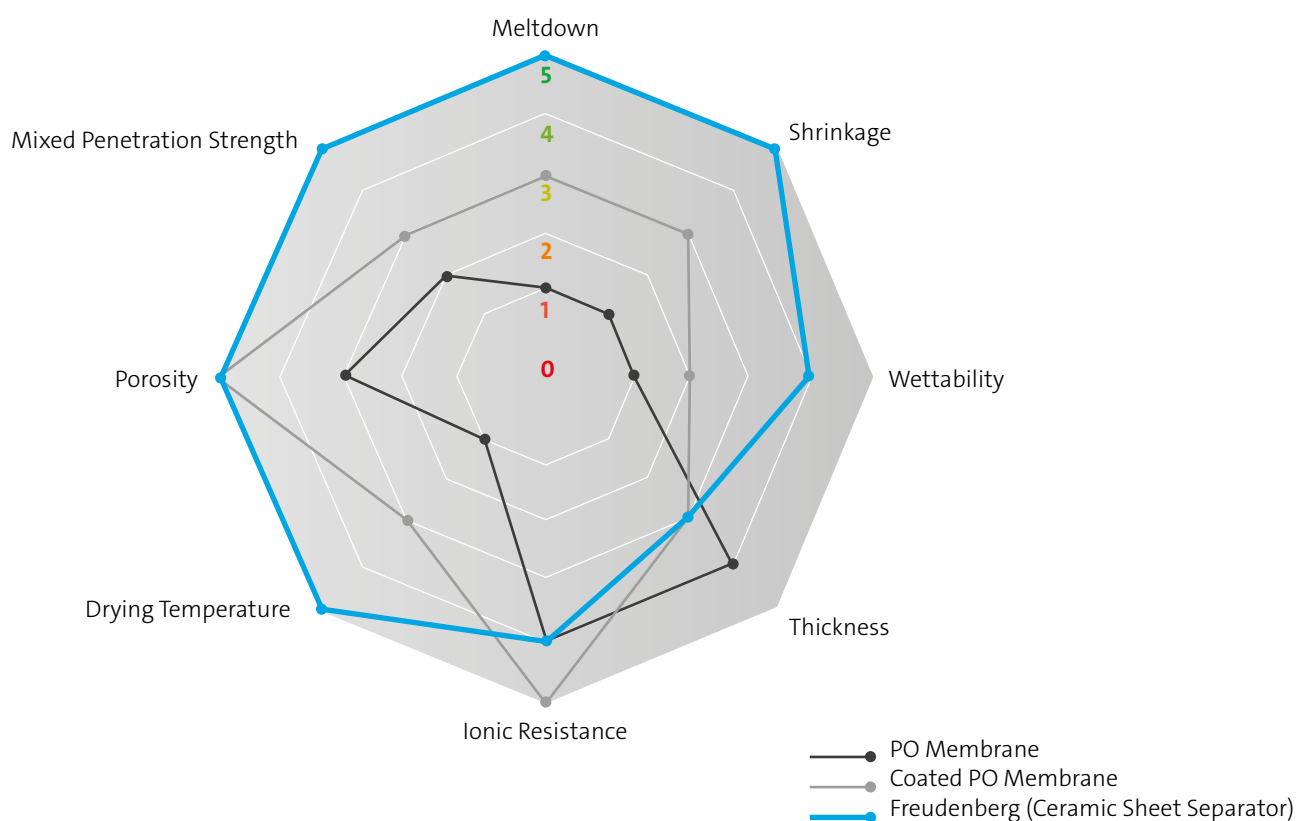
No uncontrolled discharge

No mechanical penetration of Separator by particles

MAXIMUM SAFETY IN CASE OF INTERNAL SHORT CIRCUIT

The Freudenberg separator successfully resolves the main root causes for Lithium Ion battery failures.

TECHNOLOGY BENCHMARK – THE FREUDENBERG BENEFIT



CERAMIC IMPREGNATION

HIGH PERFORMANCE, IMPROVED SAFETY

Ceramic sheet separators are manufactured in a two-step process:

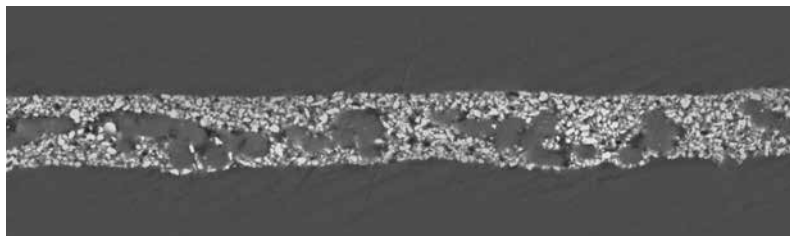
First, a thin polyester nonwoven base is manufactured in a wet laid process. Thermal stability of the separator is guaranteed by using a careful selection of microfibers. In a second step, inorganic particles are impregnated throughout the nonwoven in a water-based process using binders optimized specifically for use in Lithium Ion batteries. Afterwards the solvent is dried off leaving a microporous structure with defined properties behind.

The cross sectional view shows the unique single-layer construction of the Freudenberg ceramic sheet separator which ensures uniform porosity throughout the material.

Their superior mechanical properties allow the use of our separators in all common cell designs: cylindrical, jelly flat, z-fold or separator stack design.

Novel separator for Lithium Ion batteries

- Highly flexible, porous, Ceramic/Polyester structure



FREUDENBERG SEPARATORS ARE PROVIDING



Superior safety properties (thermal & mechanical impact)

- No shrinkage, no meltdown
- Mechanical stability against penetration



Flexibility of battery cell design

- Cylindrical, jelly flat, z-fold or stack design possible
- Complete wettability of large format power cells



Excellent high & low temperature performance

- Suitable for high temperature applications
- Permanent wettability at low temperatures & during long cycle life



Cost reduction during production

- Minimized drying time through increased drying temperature
- Faster electrolyte impregnation through high wettability
- Drying together with electrodes possible and recommended



Extended cycle life

- Minimized cell stack humidity
- No pore structure collapse



Customized separator solutions possible

- Adjustment to your production and cell environments



WORLDWIDE

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