

CELGARD



At the Center of Membrane Innovation

ELECTRIC DRIVE VEHICLES • ENERGY STORAGE SYSTEMS • SPECIALTY BATTERIES

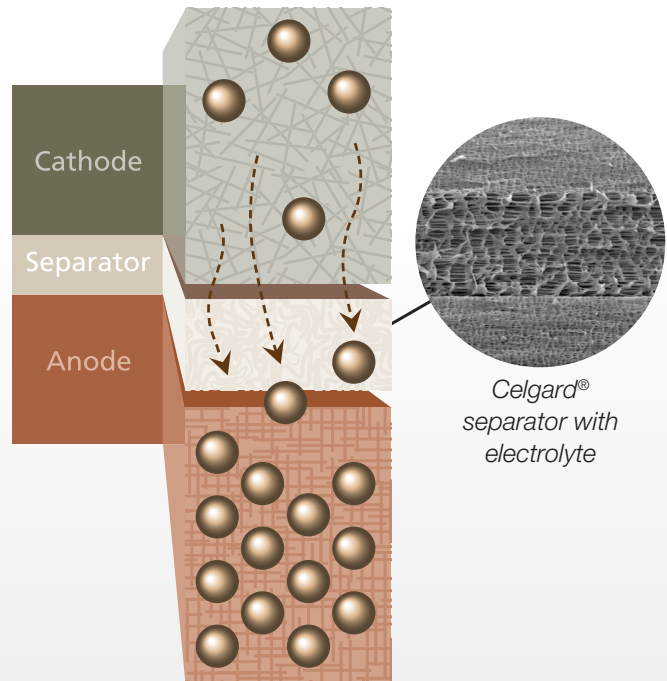


CELGARD

A Recognized Leader in Membrane Technology

Celgard is a global leader in the development and production of high-performance microporous membranes. Our family of low carbon footprint dry-process battery separators combine membrane functionality with the advantages of polymer technology. We deliver unique advantages for safety and performance in a variety of applications including:

- Lithium-Ion and Next-Generation batteries for:
 - Electric Drive Vehicles (EDV)
 - Energy Storage Systems (ESS)
- Specialty batteries



Celgard® battery separators are among the most highly engineered and critical components of a lithium-ion battery, providing a barrier between the anode and cathode while performing the core function of facilitating ion exchange.

Building on 50+ Years of Know-How

1960's

First microporous film patents granted in the late 1960s

1970's

Celgard® monolayer polypropylene (PP) membranes first introduced for use in battery cells

1980's

Full-scale development and production of Celgard® separators for primary (non-rechargeable) lithium batteries begins

Charlotte, North Carolina, USA facility is built in 1986

1990's

First commercial sales into the secondary (rechargeable) lithium-ion battery market

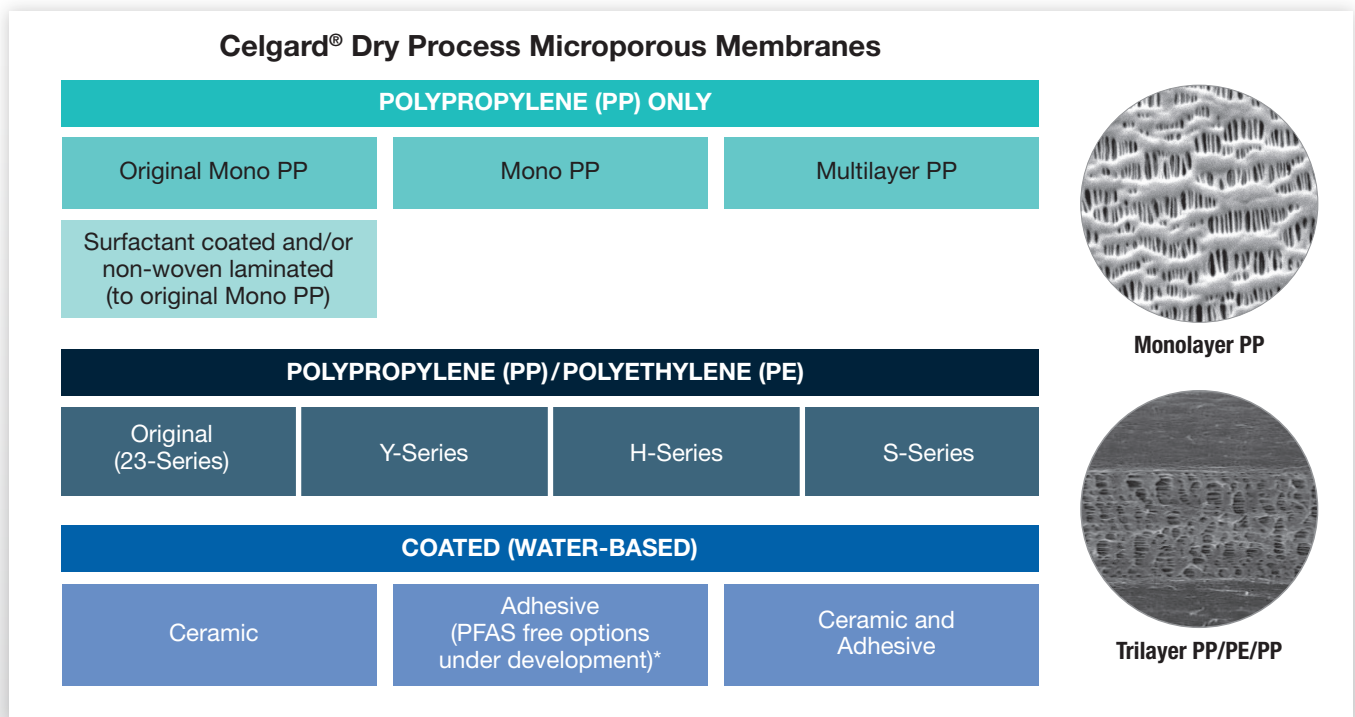
Celgard® Trilayer (PP/PE/PP) technology is developed

First expansion of the Charlotte, USA facility

Celgard has been developing and producing separators for primary lithium batteries since the early 1980s, and for secondary lithium-ion batteries since the early 1990s.

Broad Portfolio of Dry-Process Products

Celgard offers a complete range of single- and multi-layer membrane solutions. Celgard® separators are available in a variety of thickness and slit width options, with or without water-based coatings.



2000's	2010's	2020's
<p>Ceramic coated separator technology is invented**</p> <p>Expansion into Asia with facilities in China and Korea</p> <p>Additional expansions of the Charlotte, USA facility</p>	<p>Concord, North Carolina, USA facility built in 2011</p> <p>Celgard is acquired by Asahi Kasei Corporation in 2015</p> <p>Expansion of the Concord, USA facility</p>	<p>Further expansion into China with establishment of Jiangxi Enpo New Materials Co., Ltd (ENPO), a joint venture between Celgard and SEMCORP supporting the local EDV and ESS markets</p> <p>Major expansion of Charlotte, NC, USA facility announced to add HIPORE™ wet-process separator coating and finishing lines</p>

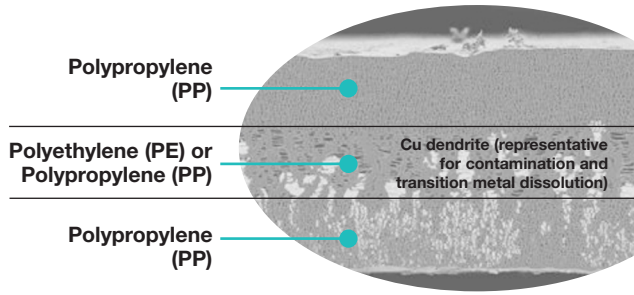
Since 2015, Celgard has operated as a subsidiary of the Asahi Kasei Group, a diversified group of companies that operates in the material, homes, and health care business sectors.

Celgard® Base Films

Celgard® offers a variety of base film options to optimize high power or energy cell applications with key advantages:

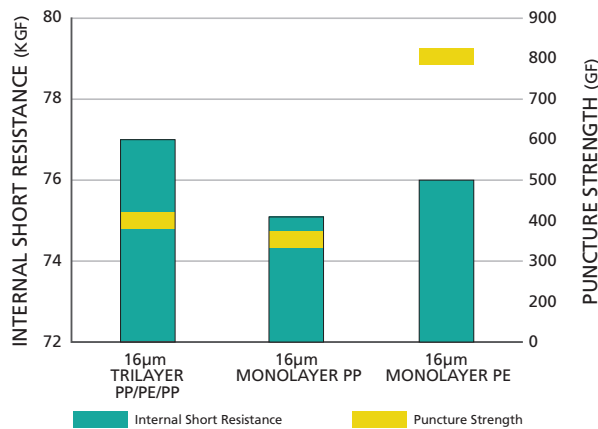
- Unique tubular (pillar-like) pore structure
- PP oxidation resistance
- Customized multilayer PP or PP/PE designs

CONTAMINATION METAL MITIGATION



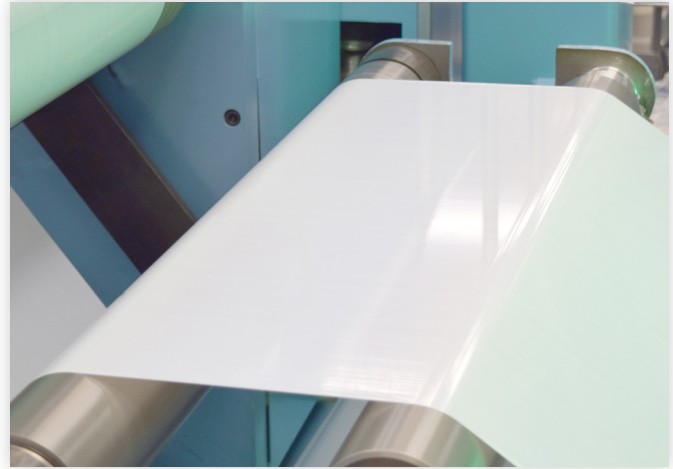
Celgard® multilayer designs may impede self-discharge due to metal mitigation properties, enhancing cell manufacturing yields and cycle life.

IMPROVED PHYSICAL INTEGRITY



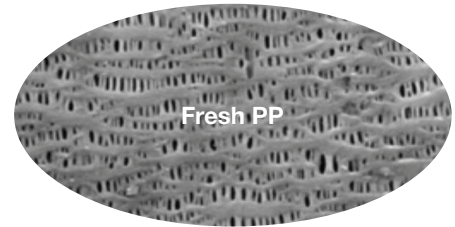
Because of their inherent mechanical strength in the z-direction, Celgard® separators have optimum compression resistance and effective internal short resistance.

- Celgard® base films are produced without the use of solvents, using a unique “dry” manufacturing process that results in a low carbon footprint.
- The polypropylene-based materials used to create Celgard® membranes are recyclable and completely perfluorocarbon (PFC) and per- and polyfluoroalkyl substances (PFAS) free*.



OXIDATION RESISTANCE

Before Floating Charge Test



Floating Charge Test at 4.35V 45°C 25 days



The oxidation resistance of Celgard® PP-based separators provides improved durability at higher voltages – allowing increased energy density designs.

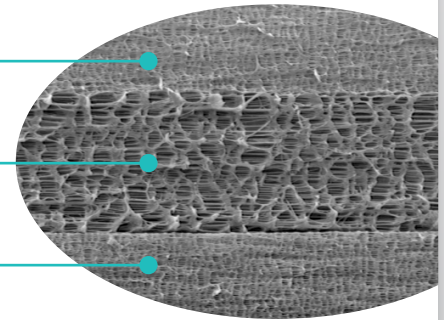
Depending on cell design and chemistry they can be used without ceramic coating – reducing separator and cell weight.

LOW TEMPERATURE SHUTDOWN & HIGH TEMPERATURE INTEGRITY

Polypropylene (PP)

Polyethylene (PE)

Polypropylene (PP)



Celgard® trilayer separators enable safer cell designs through a combination of high-speed shutdown and higher temperature integrity during thermal events.

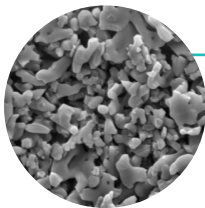


Celgard® Coated Separators

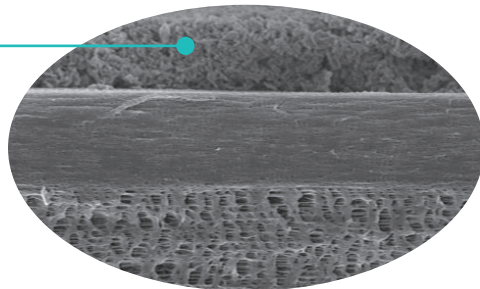
Celgard® has extensive coating capabilities to complement and add functionality to our base film offerings.

- Celgard® ceramic coated separators (CCS) offer improved safety and stability at elevated temperatures.
- Optional proprietary adhesive coatings provide strong adhesion to electrodes both before and after electrolyte filling.
- Multilayer (Ceramic and adhesive coated) separators are in advanced development stage.

CELGARD CERAMIC COATED SEPARATORS



Celgard base film coated with a ceramic layer



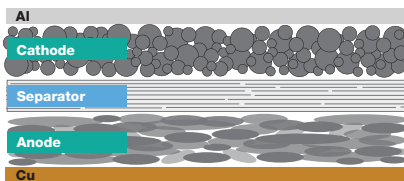
Celgard® ceramic coated separators have a 1 to 3 μm thick coating that optimizes energy density and thermal stability.

These specially processed coating components improve long-term cycle performance.

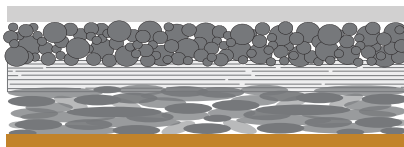
- Celgard® ceramic and adhesive coated separators are produced using water-based binders.
- PFAS free* adhesive coating options available.
- Celgard® has the **original patent position** on CCS, including US 6,432,586 “Separator for High Energy Rechargeable Lithium Battery” patents.



PROPRIETARY CELGARD ADHESIVE COATINGS



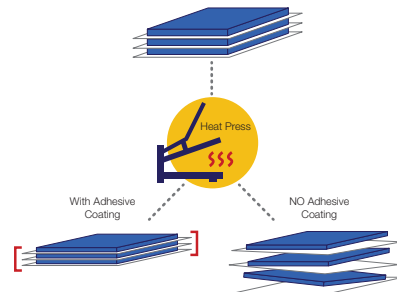
Non-laminated Single Cell Stack
No Adhesive Coating



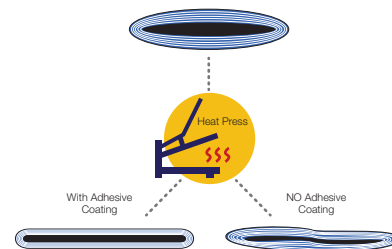
Laminated Single Cell Stack
With Adhesive Coating

Celgard's proprietary adhesive coatings enable strong separator adhesion to the electrodes – maximizing separator and cell stability at higher temperatures to increase safety and cycle life.

Stacking Process



Winding Process



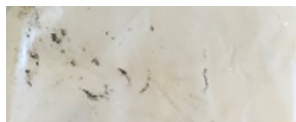
Proprietary very thin ($0.3 \mu\text{m}$ on each side) adhesive coating can enable higher lamination speeds and better stacking and heat press yields.

Separator Innovations for Next-Generation Battery Cells

Celgard has a strong, active, and growing global patent portfolio and continuously advances separator design and functionality through significant research and development.

Celgard® CyclePlus™ CYCLE IMPROVED CERAMIC COATED SEPARATORS

- Mitigate the effects of contamination and cathode transition metal dissolution to increase capacity retention and cycling uniformity at module level



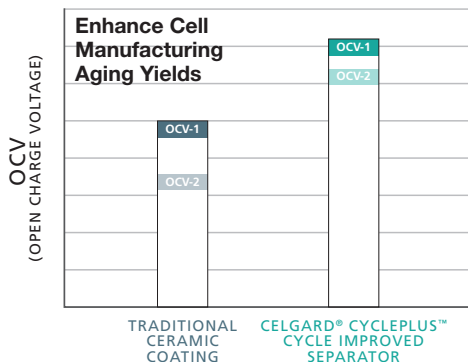
Nickel dendrite growth on traditional ceramic coated separator



Celgard® CyclePlus™ cycle improved separators after testing

Internal metal contamination tests using single-layer pouch cells show significant improvement over traditional ceramic coated separators.

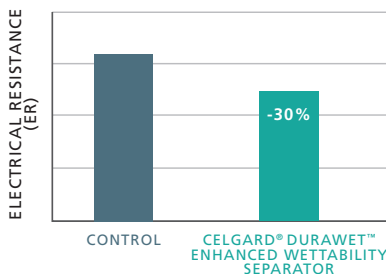
ADVANCED DEVELOPMENT STAGE



Third Party Test Conditions Contamination metal used: Proprietary to 3rd party tester.
Cathode chemistry: NMC532 2 Ah cylindrical
OCV-1: 24 h storage at RT
OCV-2: 36 h storage at 45C + 24 h storage at RT

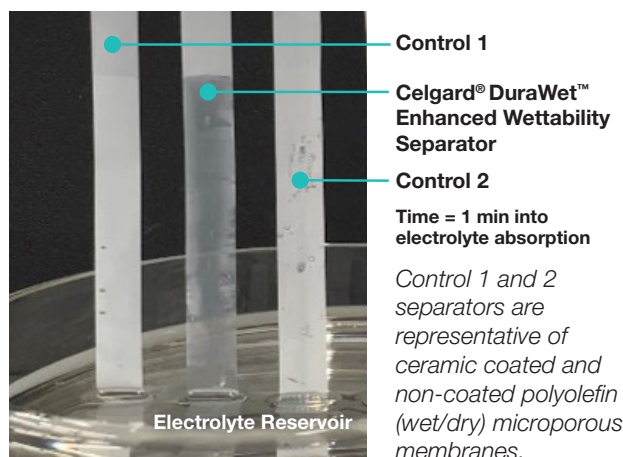
Celgard® DuraWet™ ENHANCED WETTABILITY SEPARATORS

- Improve electrolyte filling and soaking speeds, enhance long-term electrolyte retention and decrease cell scrap
- Enhance battery cycle life
- Enable low temperature battery applications



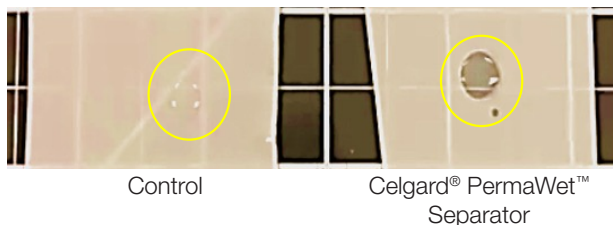
Initial testing shows an average decrease in electrolyte-separator contact angle as well as in separator electrical resistance by up to 30% relative to other polyolefin membranes.

ADVANCED DEVELOPMENT STAGE



Celgard® PermaWet™ PERMANENTLY WETTABLE SEPARATORS

Polar Electrolyte Wetting Behavior (Time = 0)



CUTTING EDGE TECHNOLOGY RESEARCH

- Internal testing shows outstanding wettability with thin, low electrical resistance separators
- Enable high energy density designs, increased hipot yield and capacity retention with no electrolyte dry-out

Next-generation Celgard® PermaWet™ Permanently Wettable Separators are instantly wetted by polar electrolytes such as propylene carbonate.

Celgard® Separator Value – Meeting Customer Needs

CATEGORY	CUSTOMER NEED	FEATURE	VALUE
COMPLIANCE	Low carbon footprint/CO ₂ emission targets (depending on regulation)	No solvent used in Celgard® dry process	Avoid potential financial penalties (due to non-compliance of applicable regulations)
TOTAL COST OF OWNERSHIP (TCO)	TCO savings for mass production customers (gigafactories)	Possibility of co-location of finishing line (slitting & packaging)	Reduced freight, packaging & storage costs
	TCO savings for all customers	Optimized solvent-free separator production Low moisture, high melting temperature (base film only) — no drying or only short duration drying needed	Cost effective cell component
BATTERY PERFORMANCE	Improved cycle life	Z-direction strength via tubular (pillar-like) structure, high resistance to external cell compression and internal compression (i.e. electrode expansion) during cycling	Longer battery usage, increased battery warranty, enable Si-containing anodes (increased energy density)
		Multilayer PP/PE/PP and/or PP/PP/PP designs help disperse contamination metals and minimize dendrite growth through the separator	Decreased cell manufacturing scrap (improved self discharge), safer cycling for longer cycle life designs like e-trucks or e-buses
		Next-generation product solutions (Celgard® CyclePlus™, Celgard® DuraWet™ and Celgard® PermaWet™ separators)	Longer battery usage, enhanced cycling uniformity at module level, enable vehicle-to-grid (V2G), second-life applications
	High power capability	Tubular (pillar-like) pore structure, tunable porosity, low tortuosity, low DC internal resistance (DCIR), stable DCIR during cycling	Enable fast charge-discharge applications
	Higher voltage applications; Increased energy density, safety and cell performance	High oxidative stability of PP and high structural integrity, coating design flexibility	Separator solutions for cost-sensitive applications (no ceramic needed or one-side coating is sufficient)
BATTERY SAFETY	Reduced risk of thermal runaway	Celgard® trilayer high-speed and low temperature onset shutdown; high temperature melting PP extends shutdown	Enable safer cell designs: High pass ratio on battery safety tests (e.g. hotbox test), overcharge, etc.
		Zero TD shrinkage of Celgard® dry separator @ 105°C for 1 hour; low MD shrinkage	Suitable for large blade (where even 1-2% TD shrinkage is critical), Z fold or wound cells (hotbox test)
		Higher temperature dimensional stability with PP	
	Thermal stability with increased energy density	Thinner, lower moisture, higher thermal stability, water based ceramic coating	Longer battery usage with increased short resistance, may enable various cathode and anode chemistries
	Durability against contamination/transition metal dissolution and lithium dendrite	Trilayer or co-ex PP base films and new ceramic coated platforms	
PRODUCTION IMPROVEMENTS	High-speed cylindrical/wound prismatic cell manufacturing	Optimized higher MD strength, Young's Modulus (e.g. Celgard® S-series separator)	Faster (high tension winding), less scrap (low rebound jelly roll insertion) cell production
	High-speed lamination or Z-fold/heat press process and increased yields	Thin, water-based adhesive coating for optimized adhesion to both electrodes, minimized separator roll self-adhesion (no interlayer)	High speed, low energy consumption manufacturing processes; Enhanced aging yields (less gassing)
		Low adhesive activation temperature	
	Enhanced yields/fast production	Next-generation product solutions (Celgard® CyclePlus™, Celgard® DuraWet™ and Celgard® PermaWet™ separators)	Decreased CAPEX via enhanced electrolyte filling and soaking, increased aging yields with added benefit of longer cycle life

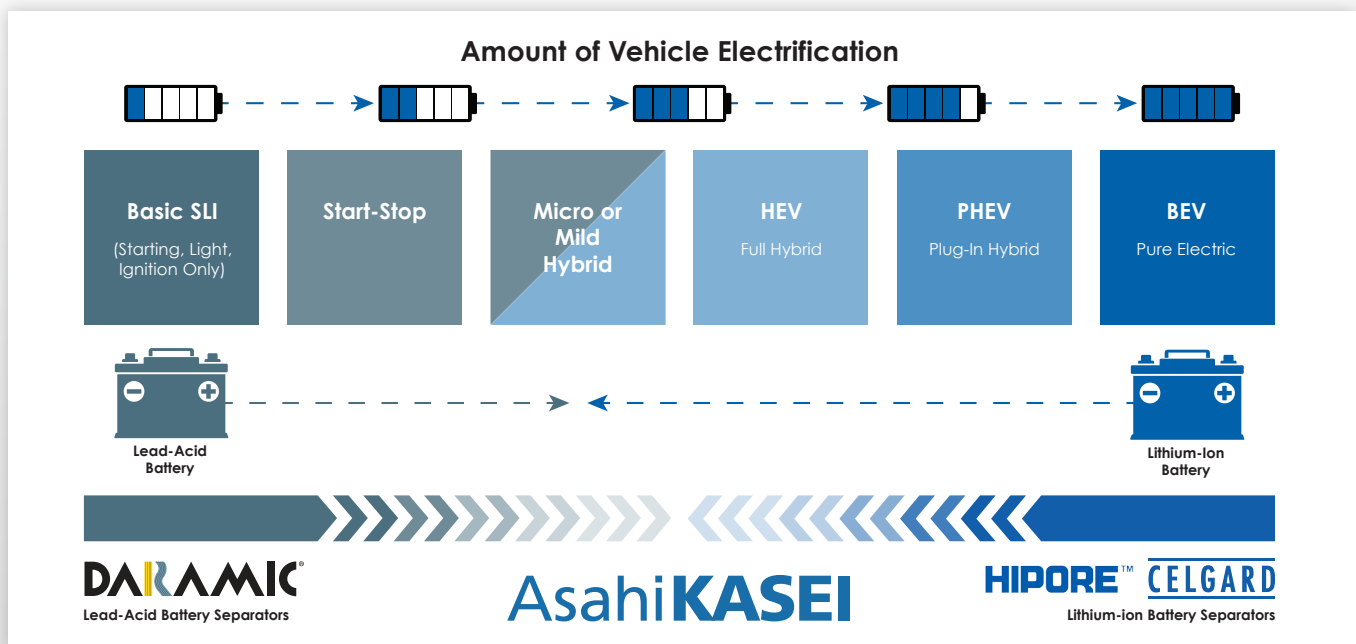
CELGARD



Celgard serves customers worldwide through three manufacturing facilities and six sales and technical service offices located throughout North America, Europe and Asia.

AN ASAHI KASEI COMPANY

Celgard is a wholly-owned subsidiary of the Asahi Kasei Group, a diversified group of companies that operates in the material, homes, and health care business sectors. Asahi Kasei develops and manufactures a large portfolio of battery separator membranes suitable for both lithium-ion and lead-acid cell chemistries.



Asahi**KASEI**

For more information or to request a sample, visit www.Celgard.com.



*Our raw material suppliers confirm they do not intentionally add PFAS and independent lab testing verifies results below the detection limit.
**US Patents 11949124, 11532854 and/or other Patents and/or Patents pending.

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