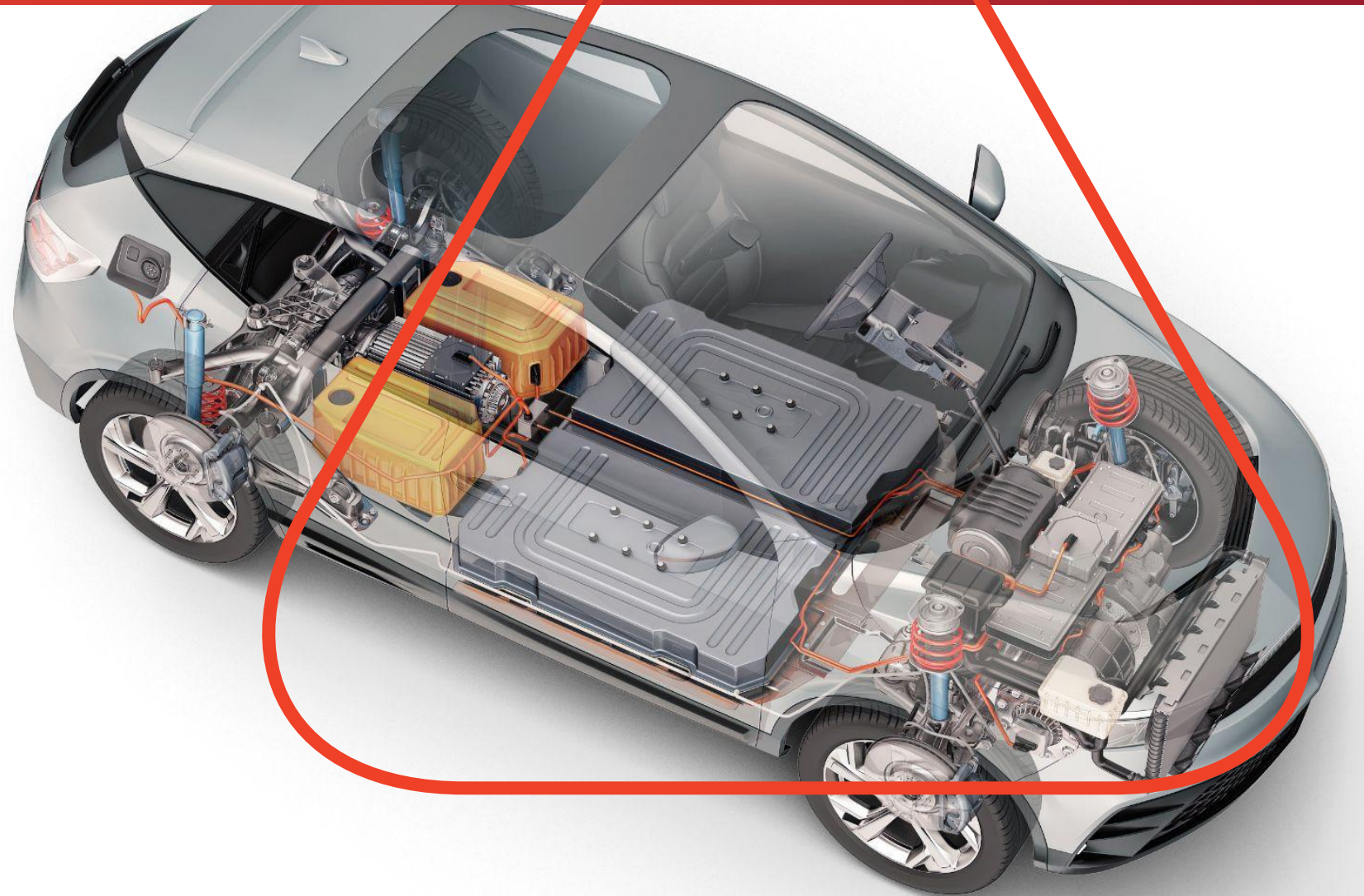


Avery Dennison Performance Tapes

How Pressure-Sensitive Adhesives Enable Advanced EV Battery Designs

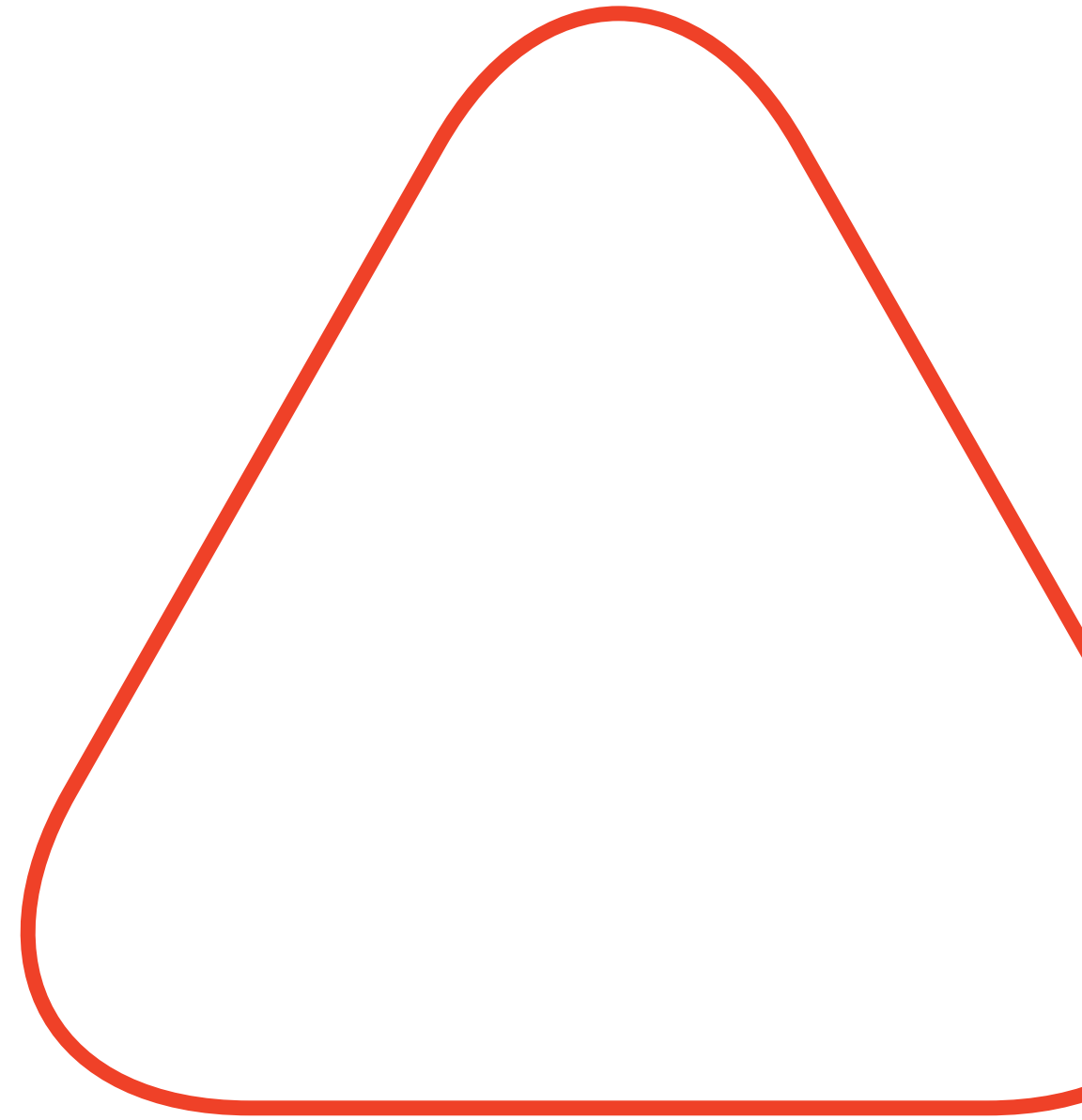
Functional bonding and protection tapes that can make EV batteries safer, more efficient and easier to assemble



Performance
Tapes

Agenda

- Pressure-Sensitive Adhesives Technical Overview
- Use of Pressure-Sensitive Adhesives in EV Battery Packs
- Design and Process Considerations
- Summary and Noteworthy Capabilities
- Q&A



Pressure-Sensitive Adhesives Technical Overview

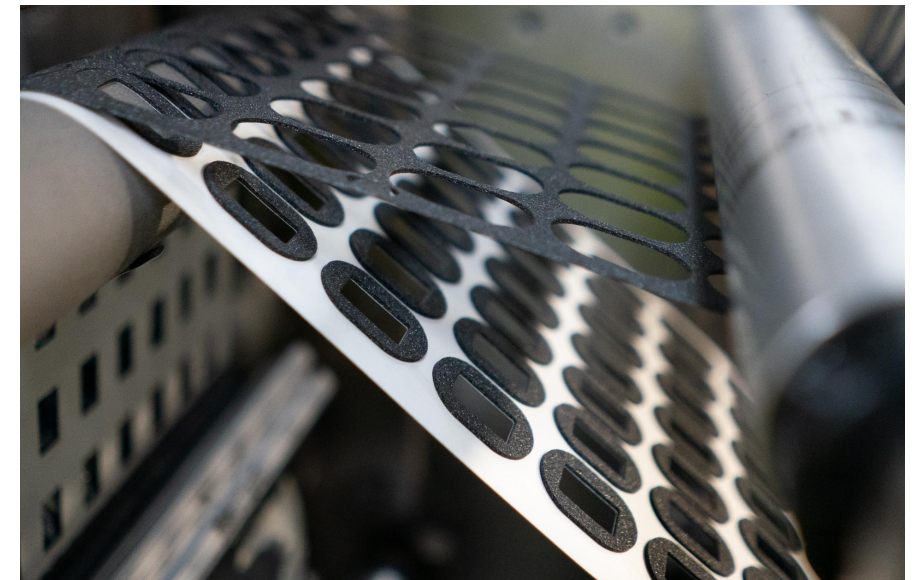


Performance
Tapes

Pressure-Sensitive Adhesive Tapes and PSA Backed Materials

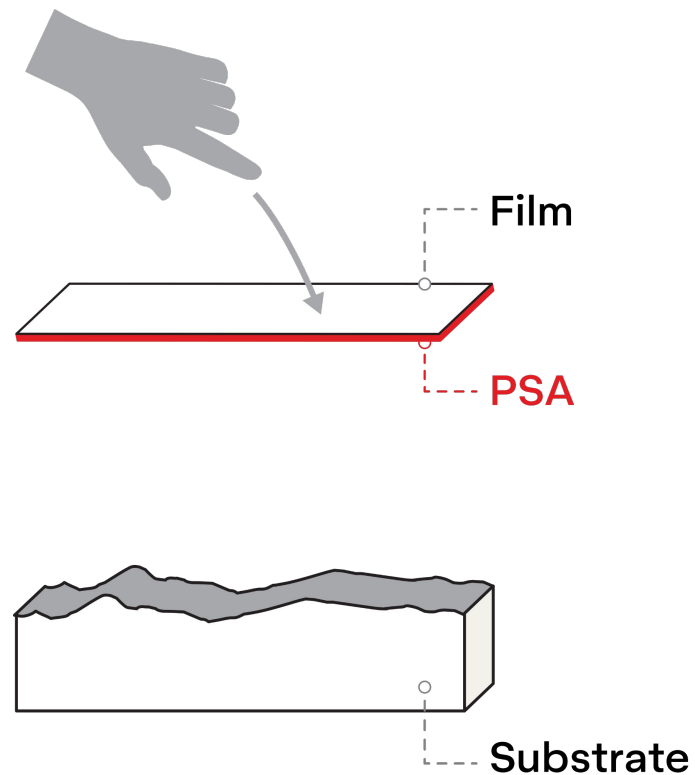
Pressure-sensitive adhesive tapes can be either the primary solution or an accessory bonding method for functional materials designed to address challenges in the pack.

Functional materials, such as foams, fibers and films, can be laminated and die cut with pressure-sensitive adhesive tapes.

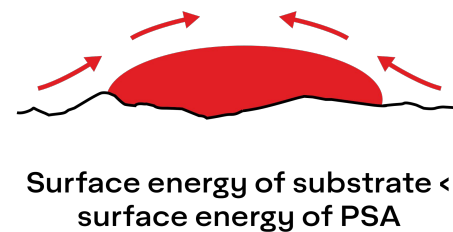
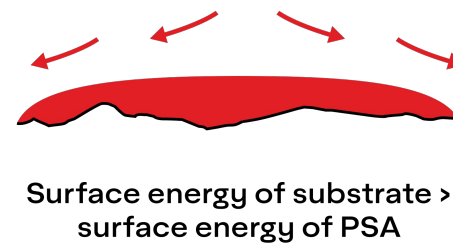


How Pressure-Sensitive Adhesive Technology Works

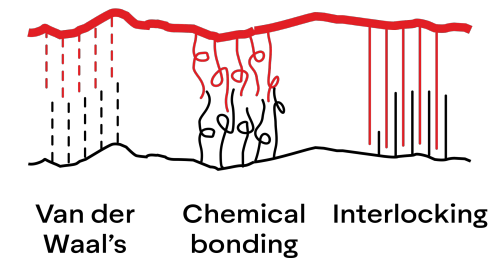
Pressure-sensitive adhesives form a bond with a material upon contact under light pressure. This pressure plays a part in each of the methods by which a tape sticks to the substrate.



Work of Adhesion



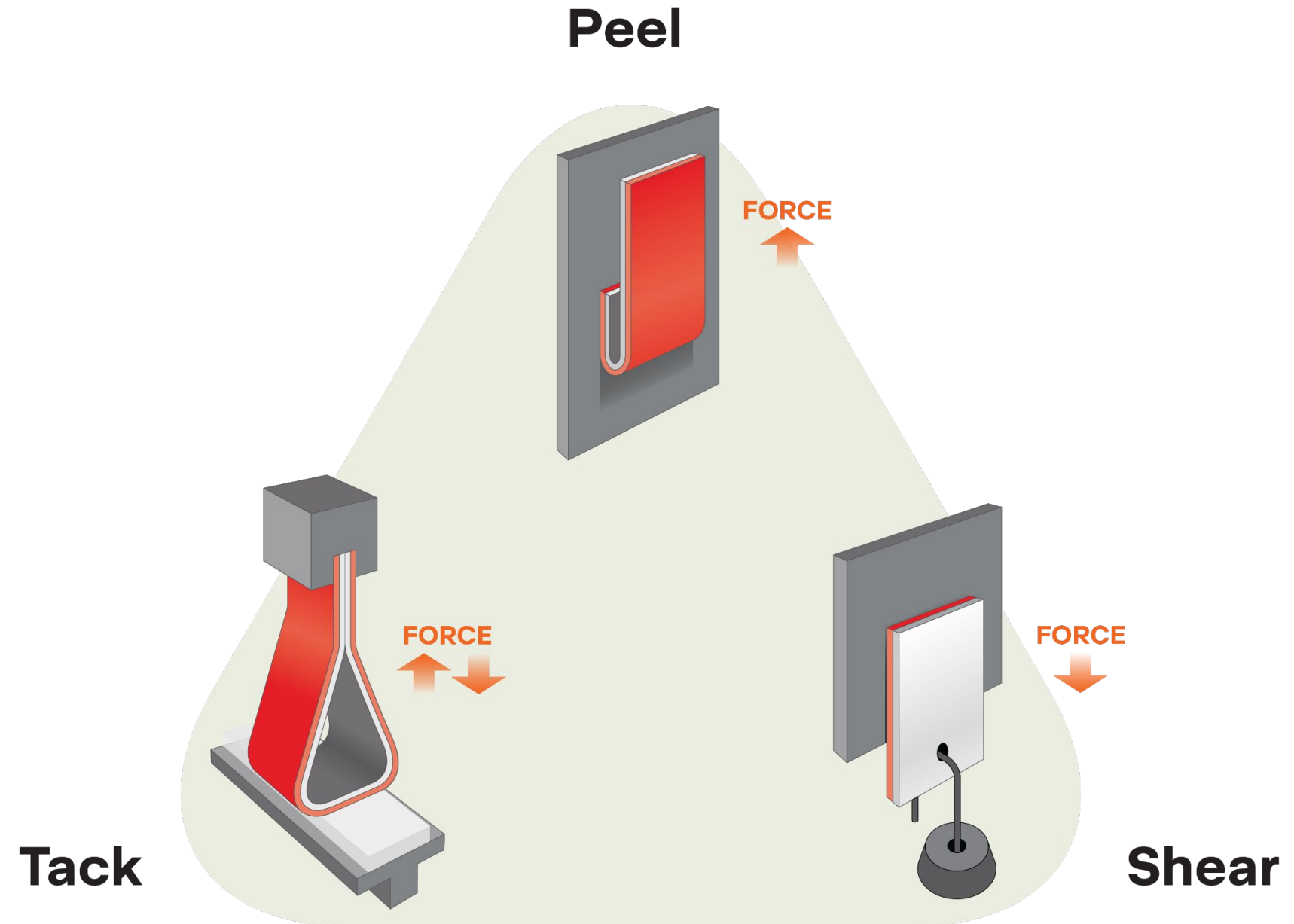
Intermolecular Forces



Pressure-Sensitive Adhesive Key Performance Factors

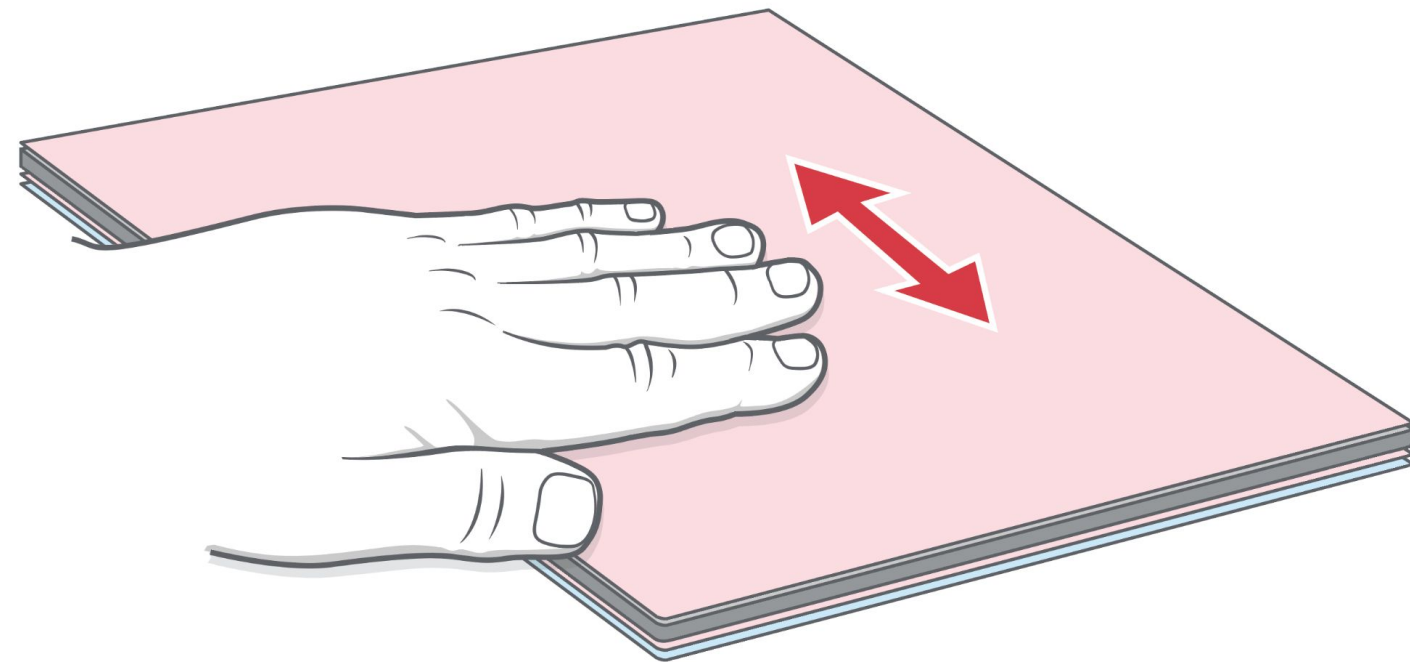
Holding Power

Adhesives balance peel, tack, and shear for long-term stability and performance.

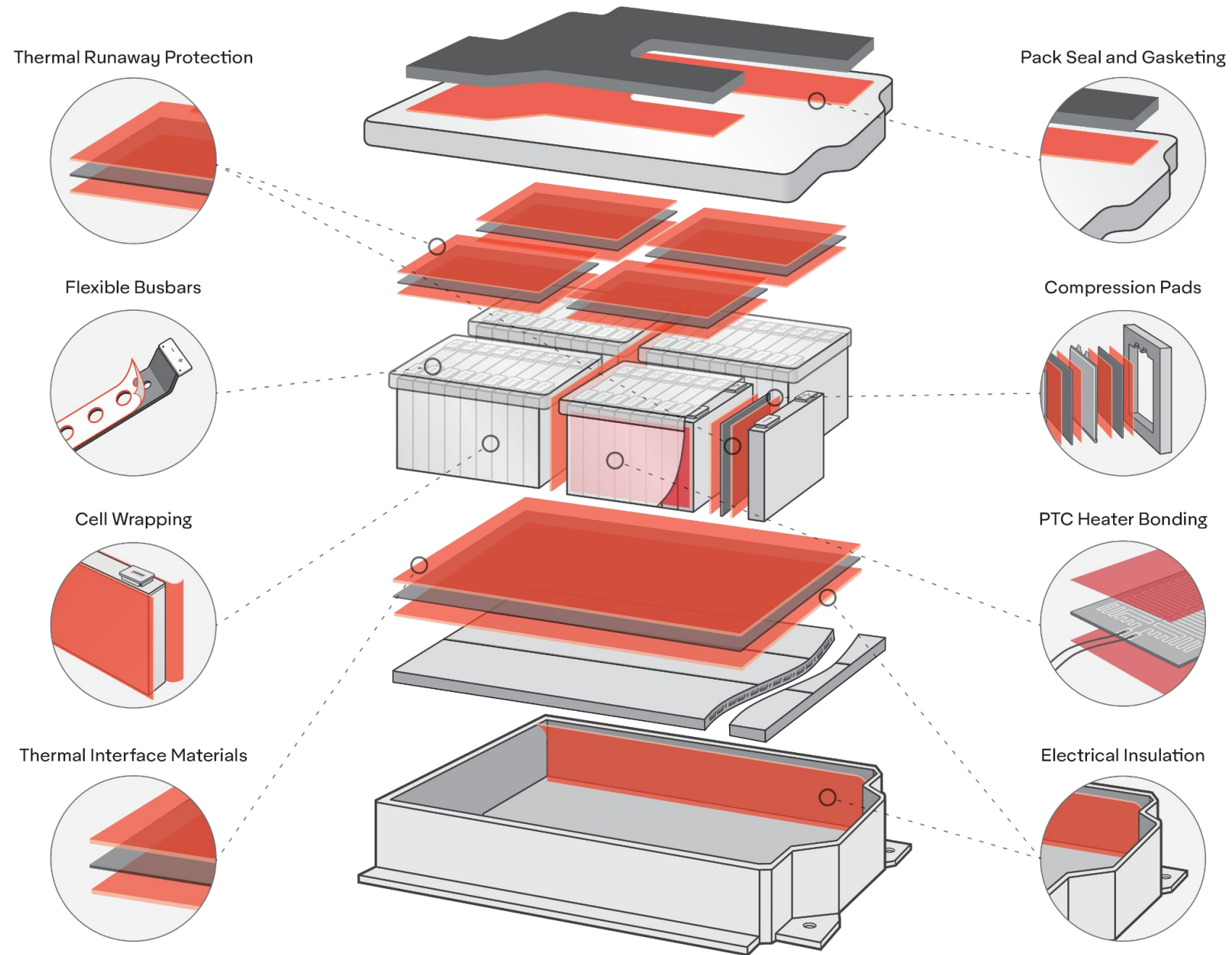


Benefits of Pressure-Sensitive Adhesive Tapes

- As a Bonding Solution
 - Uniform Coverage
 - Elimination of Mechanical Fasteners
 - Low Tooling and Capex Costs
 - Lightweight
 - Slim Profiles and Tight Tolerances
 - No Cure Time — High Productivity
 - Bonding of Dissimilar Materials
- Beyond Bonding
 - Design Flexibility
 - Multilayer Functionality
 - Gap Filling and Sealing
 - Dimensional Stability
 - Encapsulation
 - Insulation



Pressure-Sensitive Adhesive Tapes for EV Battery Applications



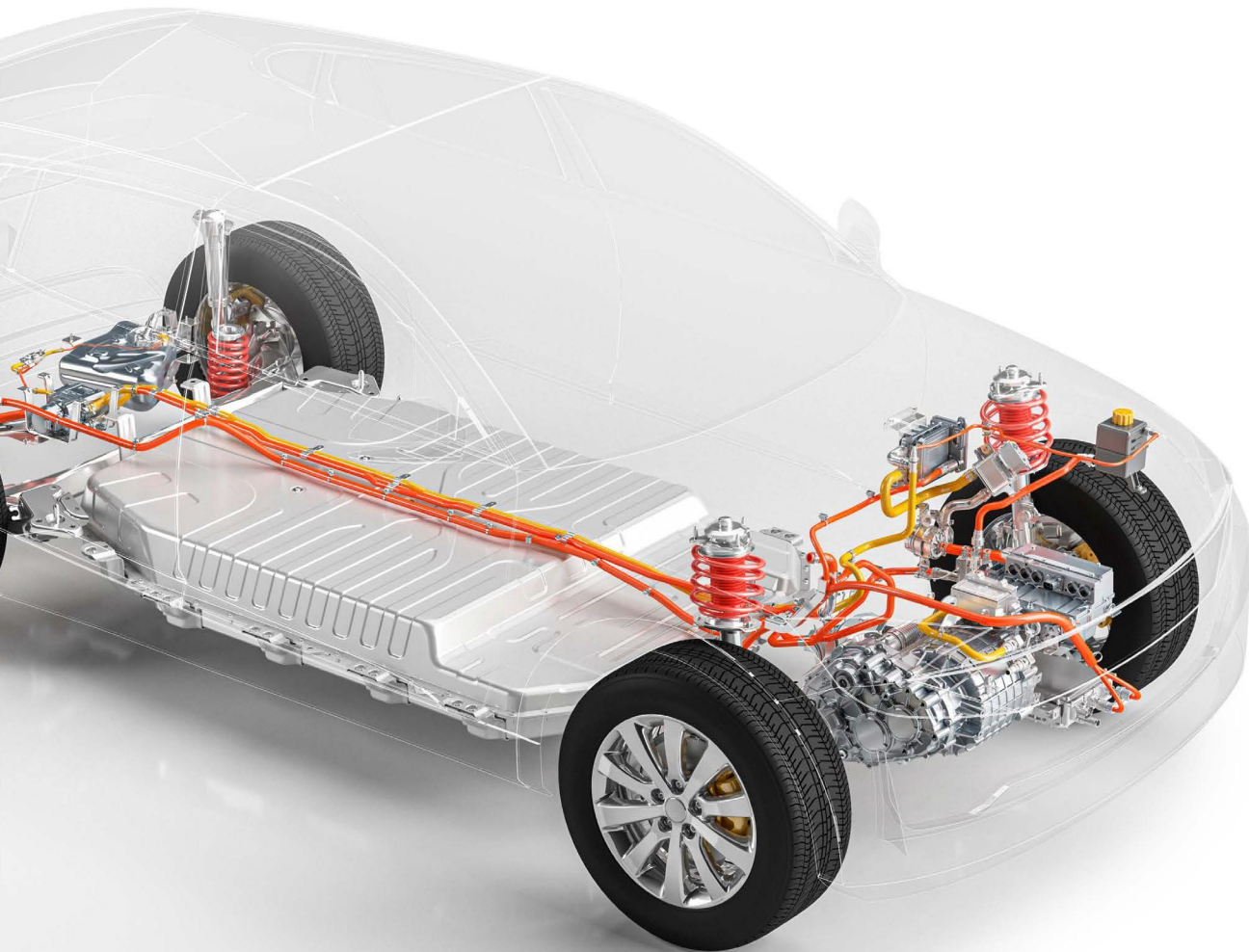
Use of Pressure-Sensitive Adhesives in EV Battery Packs



Performance
Tapes

Solutions for Common Challenges

The Avery Dennison EV Battery Portfolio can help you solve for some of the most common challenges in battery design and construction



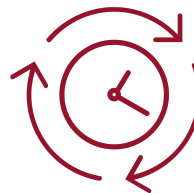
Reducing flammability

Acrylic-, rubber- and silicone-based adhesives with Flame Tough™ flame-retardant properties that allow composites and materials to meet UL® 94 V-0 and other flame requirements.



Boosting Dielectric Strength

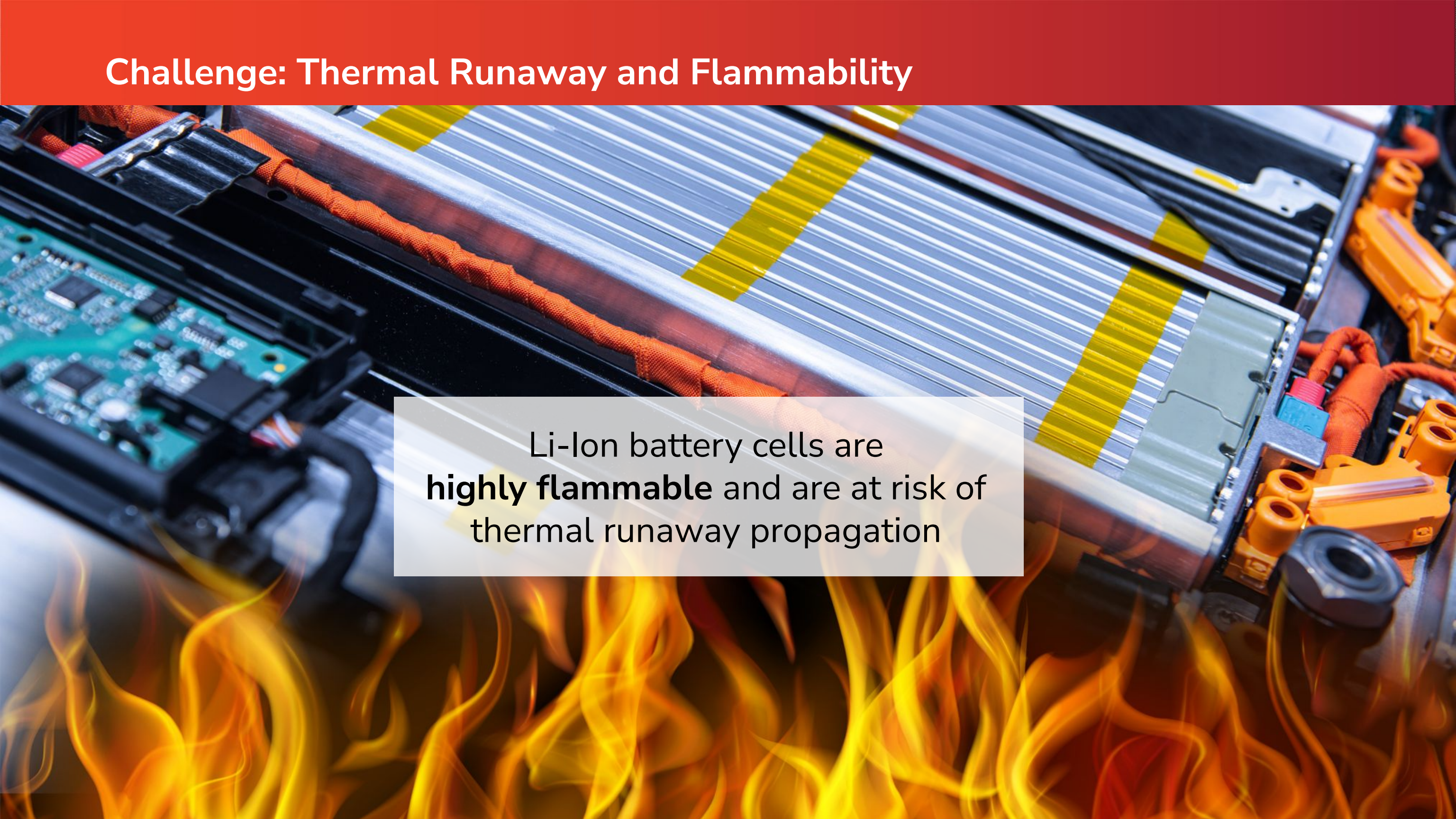
Single-coated Volt Tough™ tapes and double-coated tapes which incorporate dielectric films. Our materials and adhesives are tested for breakdown voltage and dielectric strength requirements using GB/T 1408.1-2016 and ASTM D3755 test methods.



Optimizing design and assembly

Functional tapes that can replace mechanical fastening methods while offering a thinner profile, lighter weight, repositionability and instant bond

Challenge: Thermal Runaway and Flammability

A close-up photograph of a Li-ion battery pack, showing the metallic casing with yellow and black hazard stripes. The battery is connected to a green printed circuit board (PCB) with various electronic components. The bottom of the image is overlaid with a bright, intense fire, symbolizing the risk of thermal runaway and flammability.

Li-Ion battery cells are **highly flammable** and are at risk of thermal runaway propagation

Tapes Used with Thermal Runaway Barriers

Thermal Runaway Protection

Tapes to encapsulate and bond materials used to prevent or slow thermal runaway events

Between Cells

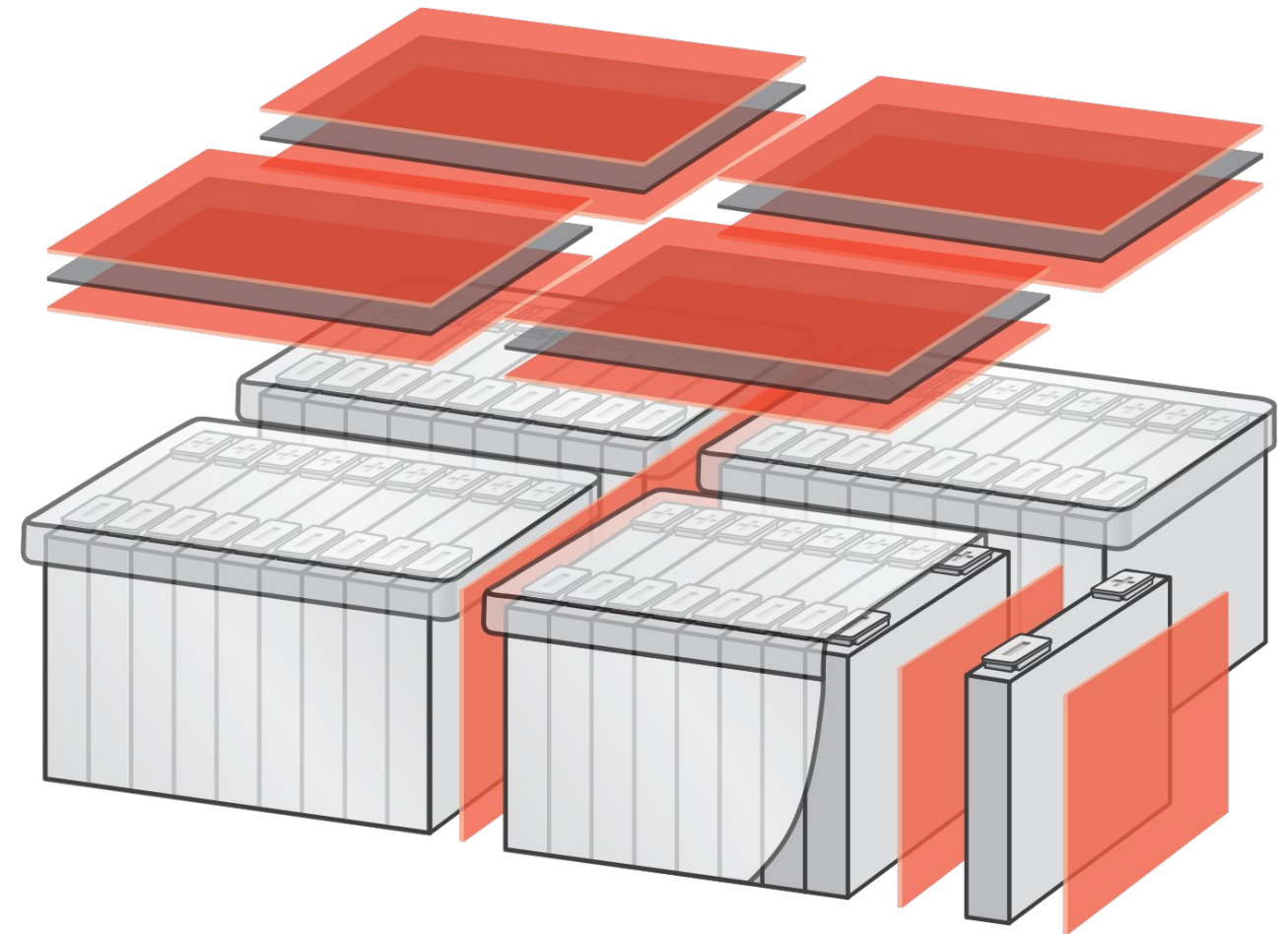
Prevents or drastically slows cell-to-cell thermal propagation. Tapes can encapsulate materials, be an assembly aid, and provide dielectric strength.

Module Level

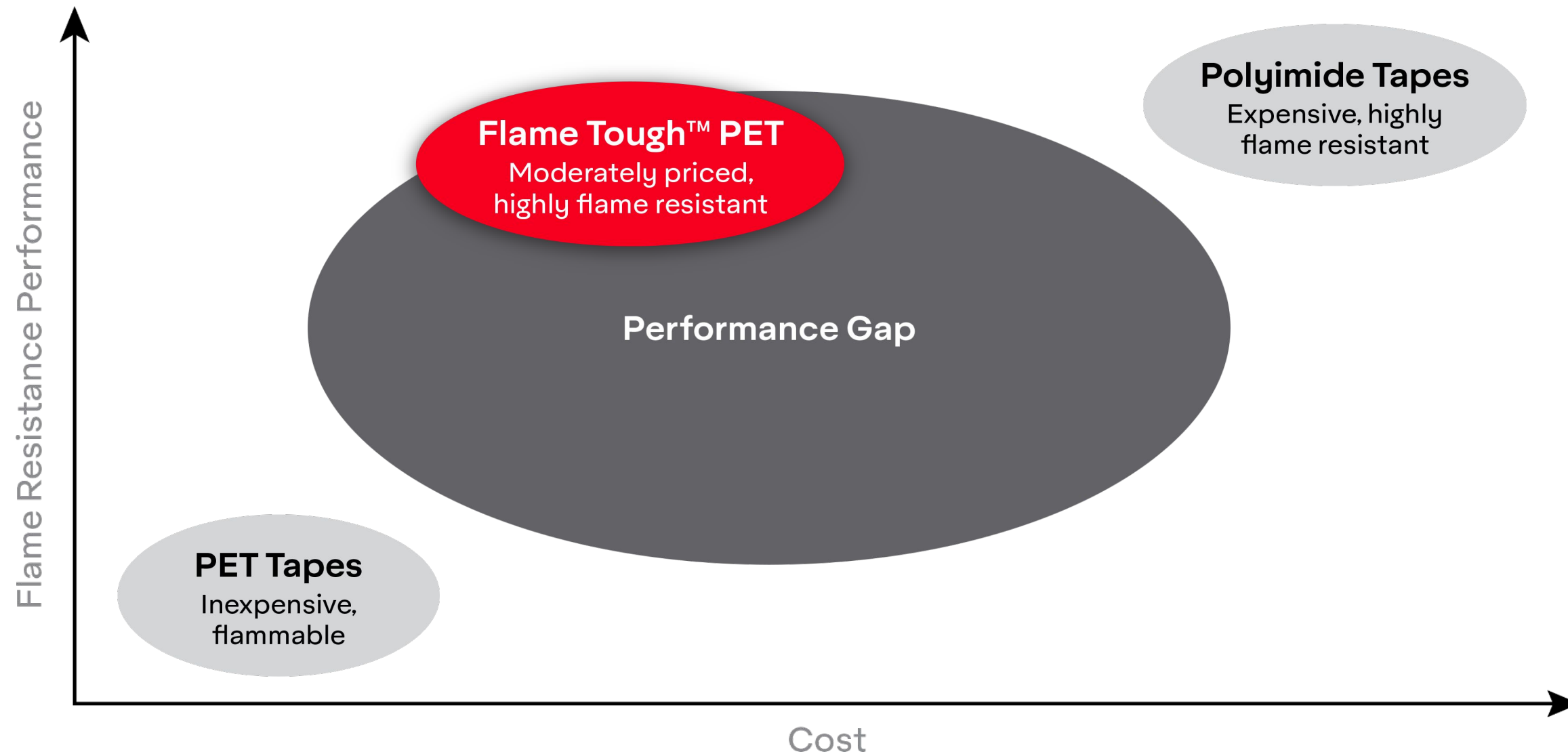
Protects one module from another. Tapes are used to bond and encapsulate module-level protection. Visco-elastic behavior helps with vibration management.

Pack Level

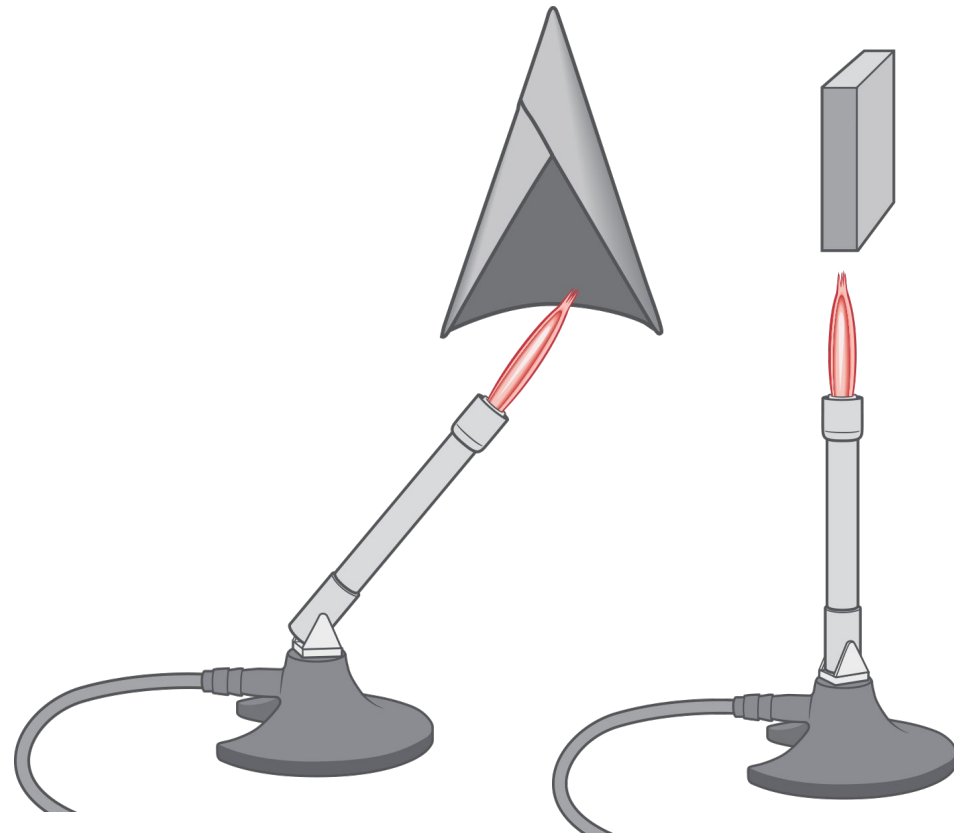
Typically found on the lid, but is used to ensure enough time for occupants to leave vehicle. Tapes are often used as an assembly aid to hold part in place



Beyond Dielectric Strength: Reduced Flammability



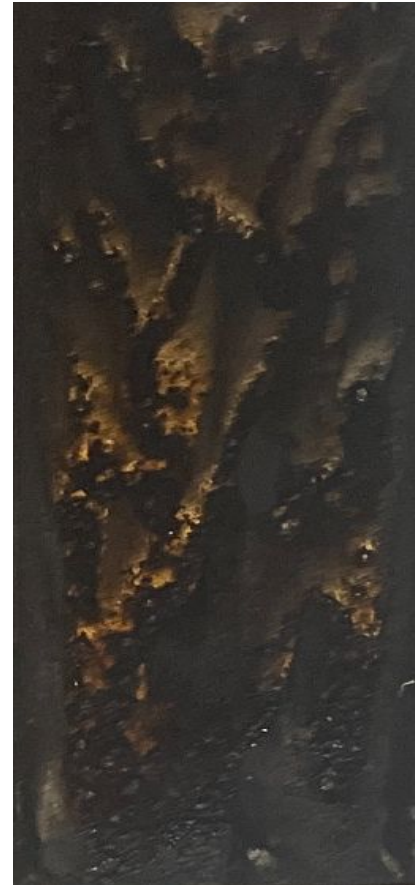
Performance: Flame Tough™ Tape Platform



UL® 94VTM
(Shown at right)

UL® 94V

FAIL



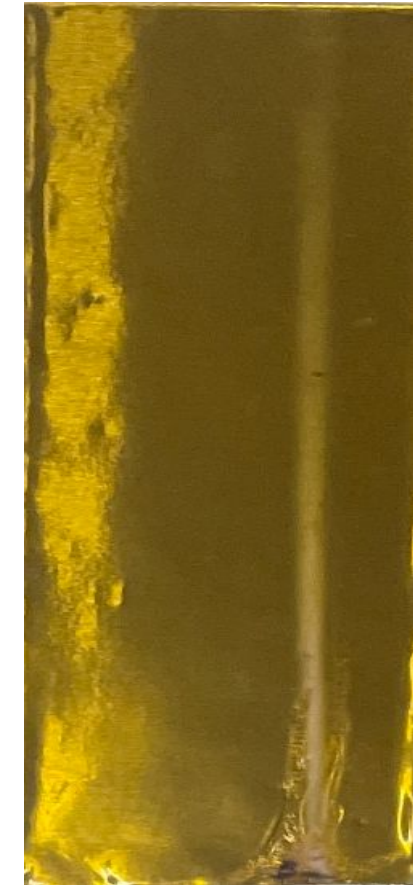
Traditional
Non FR
PET/Acrylic

PASS



FT 0065:
Flame Tough™
PET/Acrylic

PASS



FT 0975:
Flame Tough™
PI/Silicone

Flammability Testing is Complex

Individual Testing

Single Coated Tape - **Passes** UL[®] 94 VTM-0



Ceramic Paper - **Passes** UL[®] 94 V-0



Multi-layer Testing

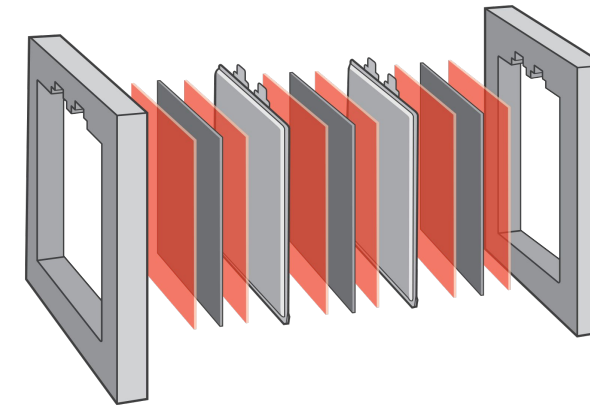
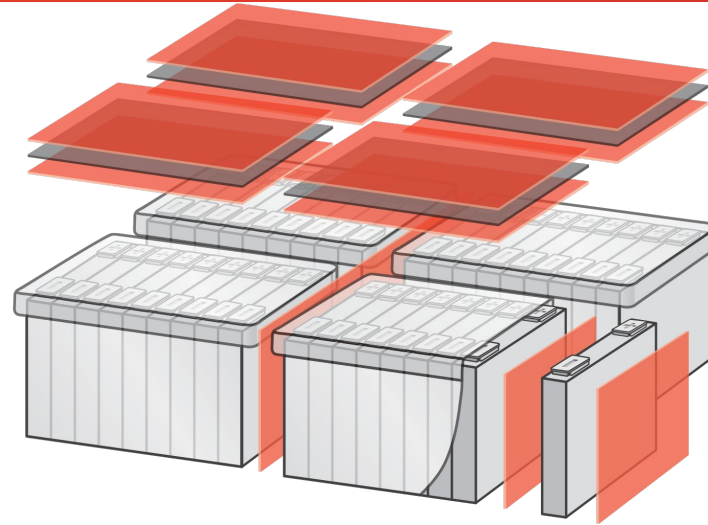
Tape + Aluminum = **Passes** UL[®] 94V-0



Tape + Ceramic Paper = **Fails** UL[®] 94V-0



Thermal Barriers Encapsulation and Bonding



	Encapsulation			Bonding				
	No FR	Med FR	Best FR	FR Rated		General Bonding		
Benefits	Very Thin Cost Effective	FR Adhesive White PET	FR Facestock FR Adhesive	FR Thinnest	FR Heavier Bodied	Ceramic Papers EZ release	Higher Temps vs 8383EZ	Foam Tape Rigid Mica
Name	FT0011	FT0333	FT0065	FT9850	FT8065	FT 8383EZ	FBA8960	FM2333
Facestock(s)	PET	PET	Flame Tough™ PET	PET	Flame Tough™ PET	PET	PET	PE Foam
Adhesive	Emulsion Acrylic	Flame Tough™ Acrylic	Flame Tough™ Acrylic	Flame Tough™ Acrylic	Flame Tough™ Acrylic	Rubber	Acrylic	Acrylic
Total Thickness, mil (micron)	1.0 (25)	2.0 (50)	3.6 (92)	2.0 (50)	5.6 (142)	3.3 (84)	4.0 (102)	35.6 (904)
Dielectric Strength, kV	3.1	4.3	5.1	2	6.1	3.1	3.1	
UL 94 VTM		VTM-1	VTM-0	VTM-0	VTM-0			
Notes	Linerless, Clear	White	White		Zone Coatable	Zone Coatable	Zone Coatable	Gap Filling

Tapes for Dielectric Protection

Importance of Electrical Insulation

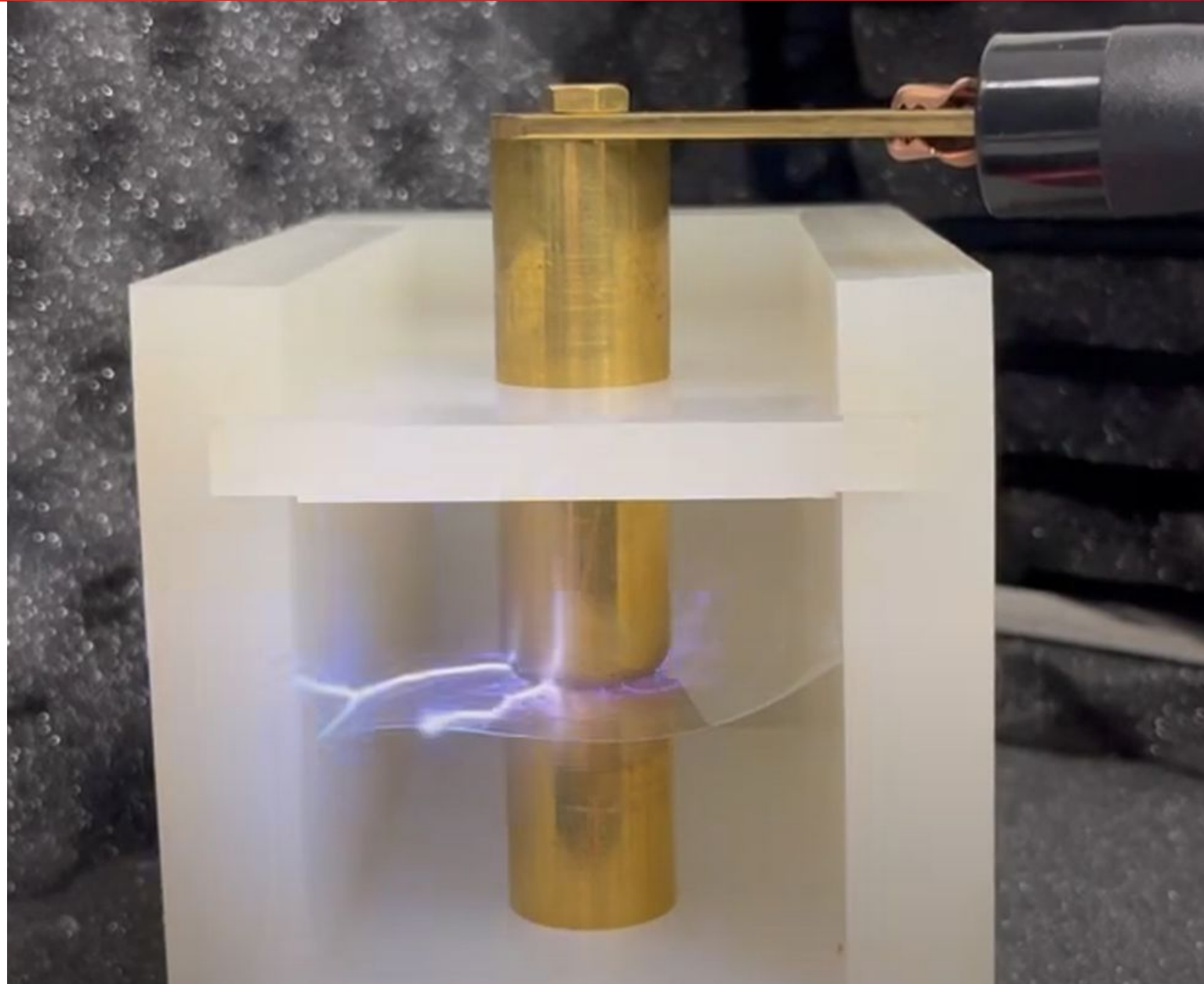
Without electrical insulation, current can arc between cells and to other conductive components. Arcing can result in:

- Short circuiting
- Fire and thermal runaway
- Electrocution

Boosting Dielectric Strength

PSA tapes are combined with dielectric films to reduce electrical conductivity and arcing

Tapes are tested for breakdown voltage and dielectric strength requirements using GB/T 1408.1-2016 and ASTM D149 and D3755 test methods



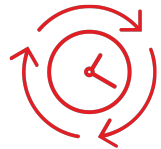
Volt Tough™ Benefits

PSA tapes play an integral role in electrical insulation.



High dielectric strength with thin profiles

Higher pack energy density



Instant bond; no curing time/space needed

Faster production times



Conformable versions available

Resistant to tearing when shaped around complex geometries and corners



Durable and tear-resistant versions available

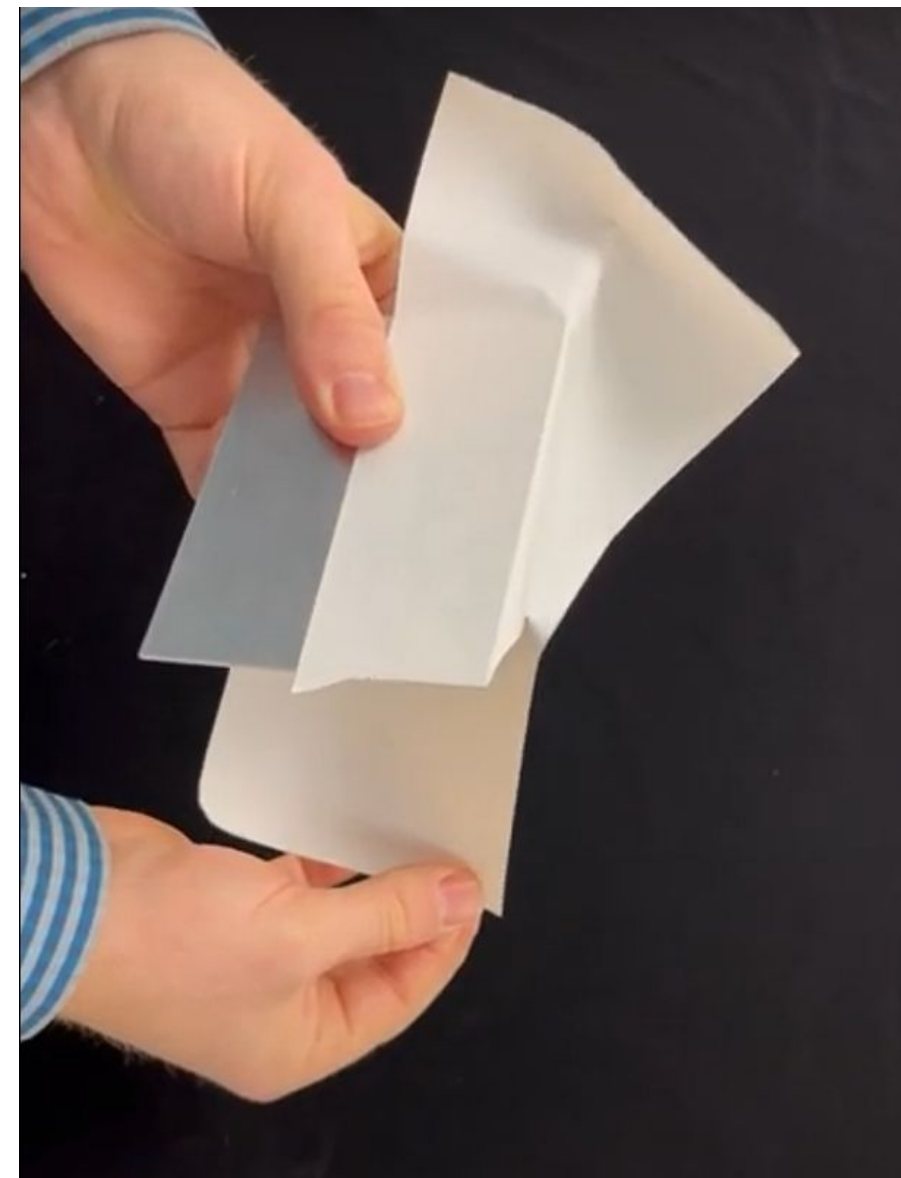
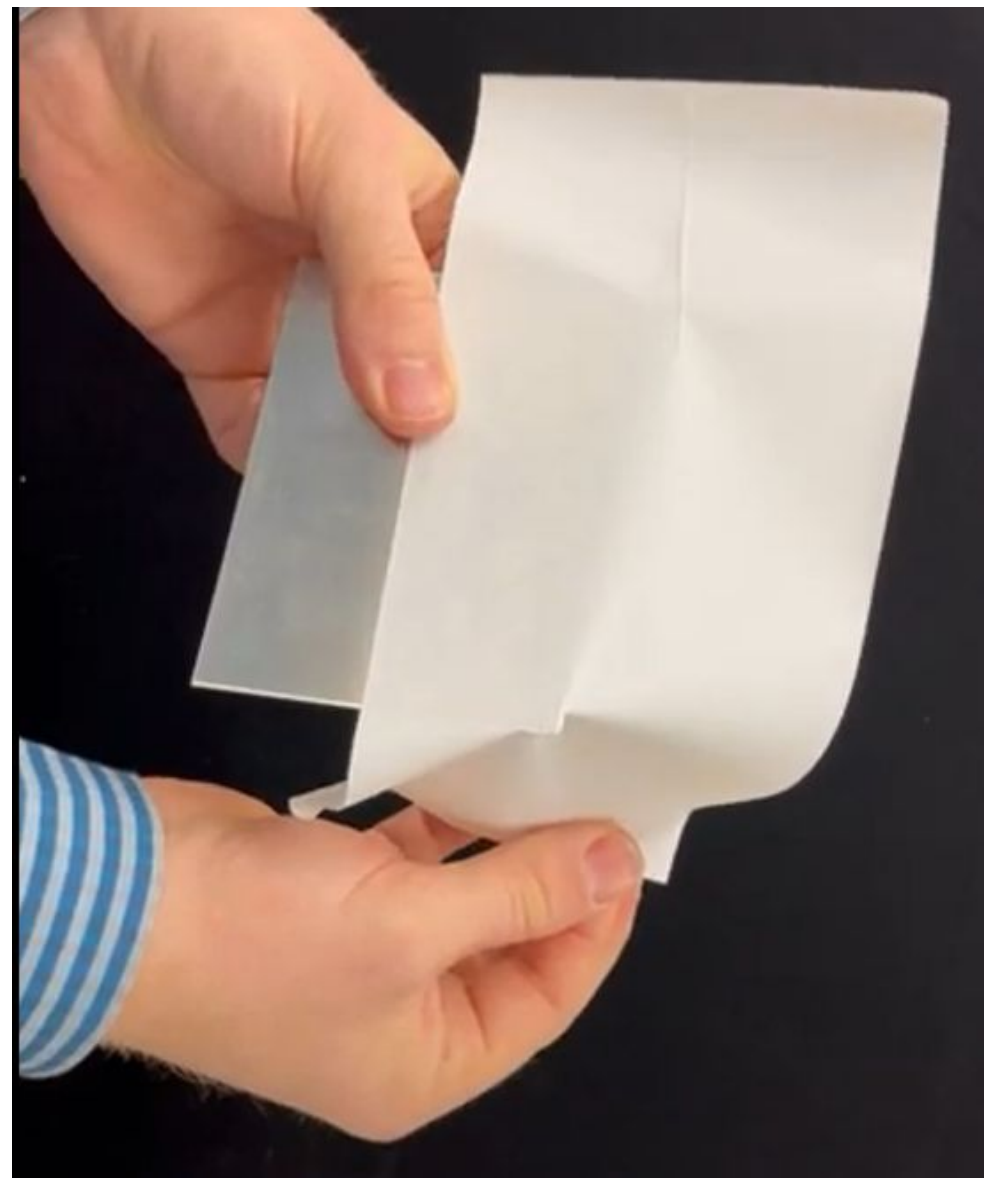
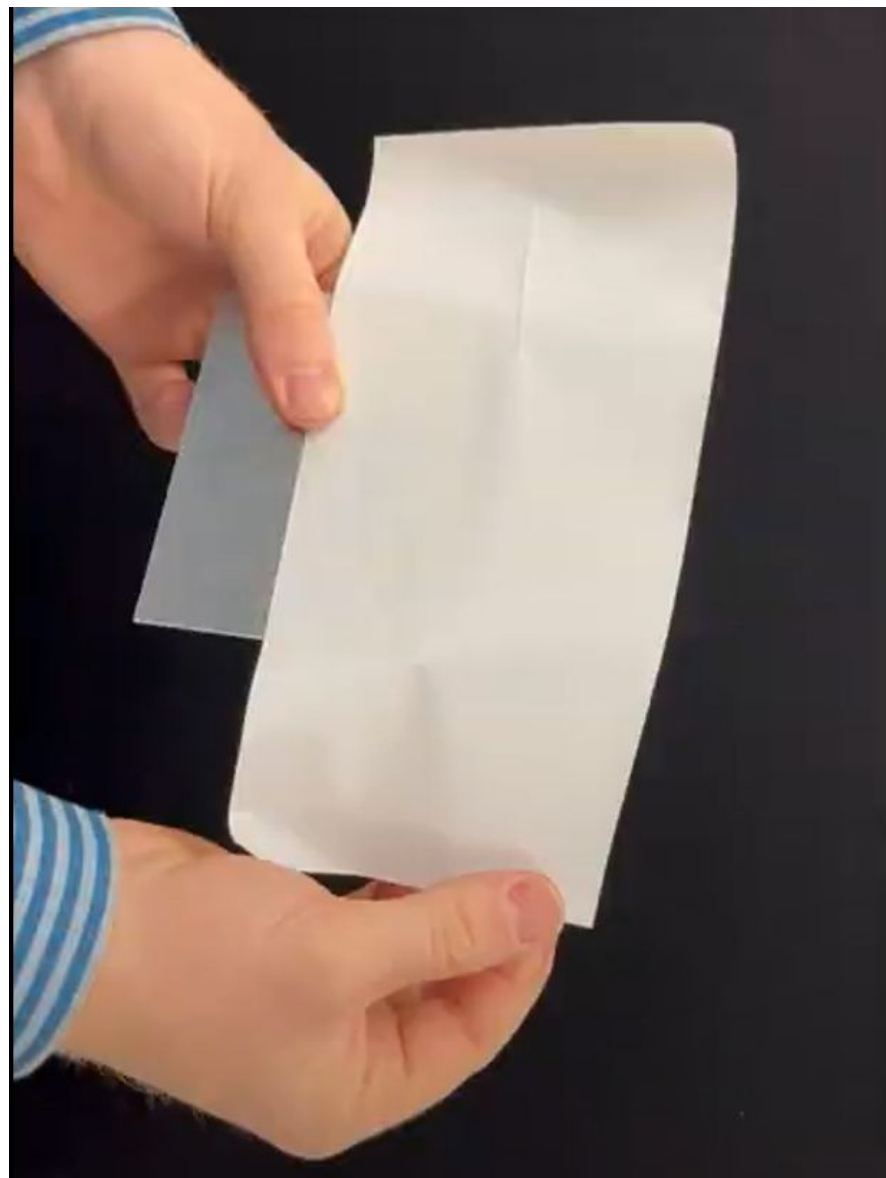
Protects against sharp corners, burrs and external impact that could cause other tapes and coatings to fail



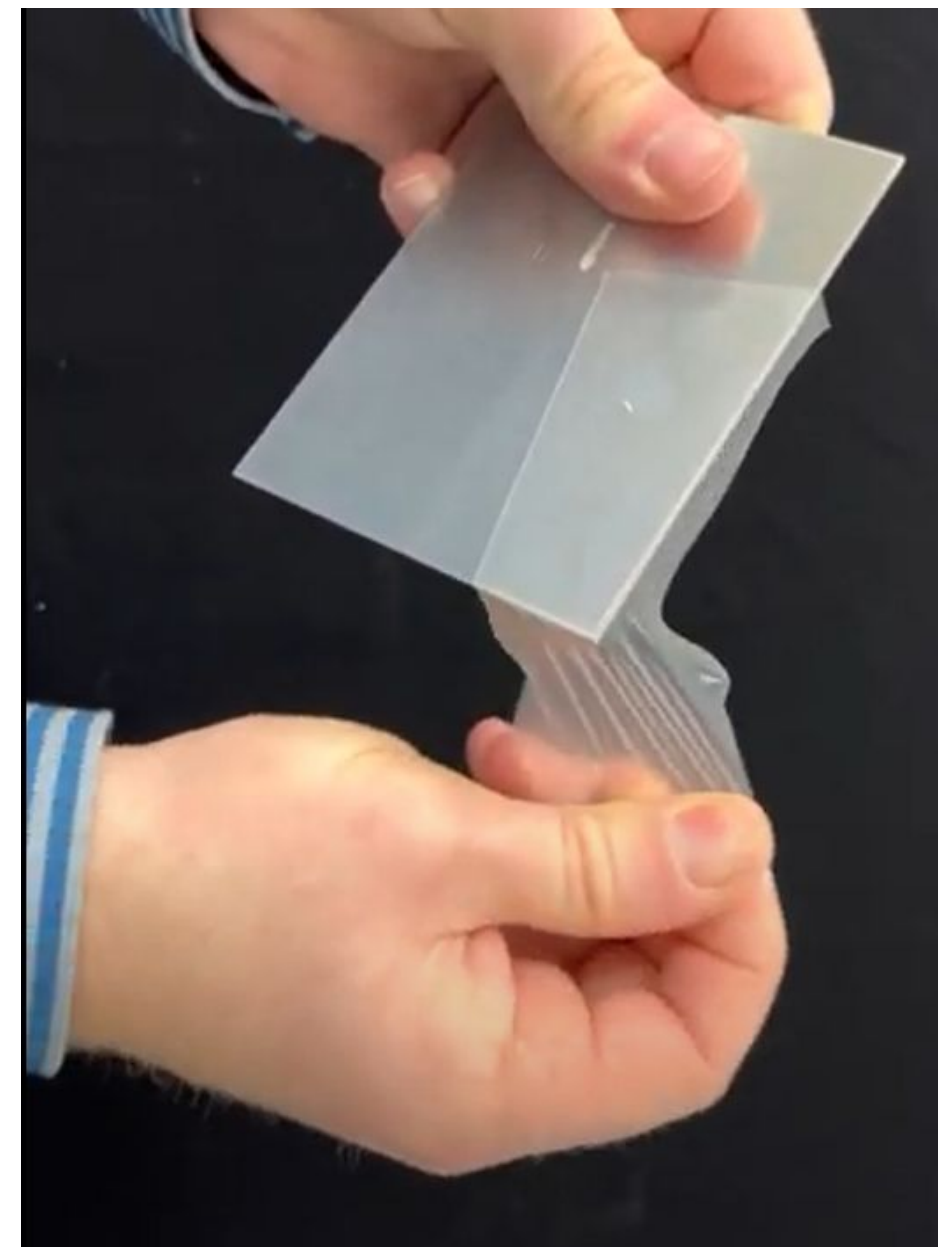
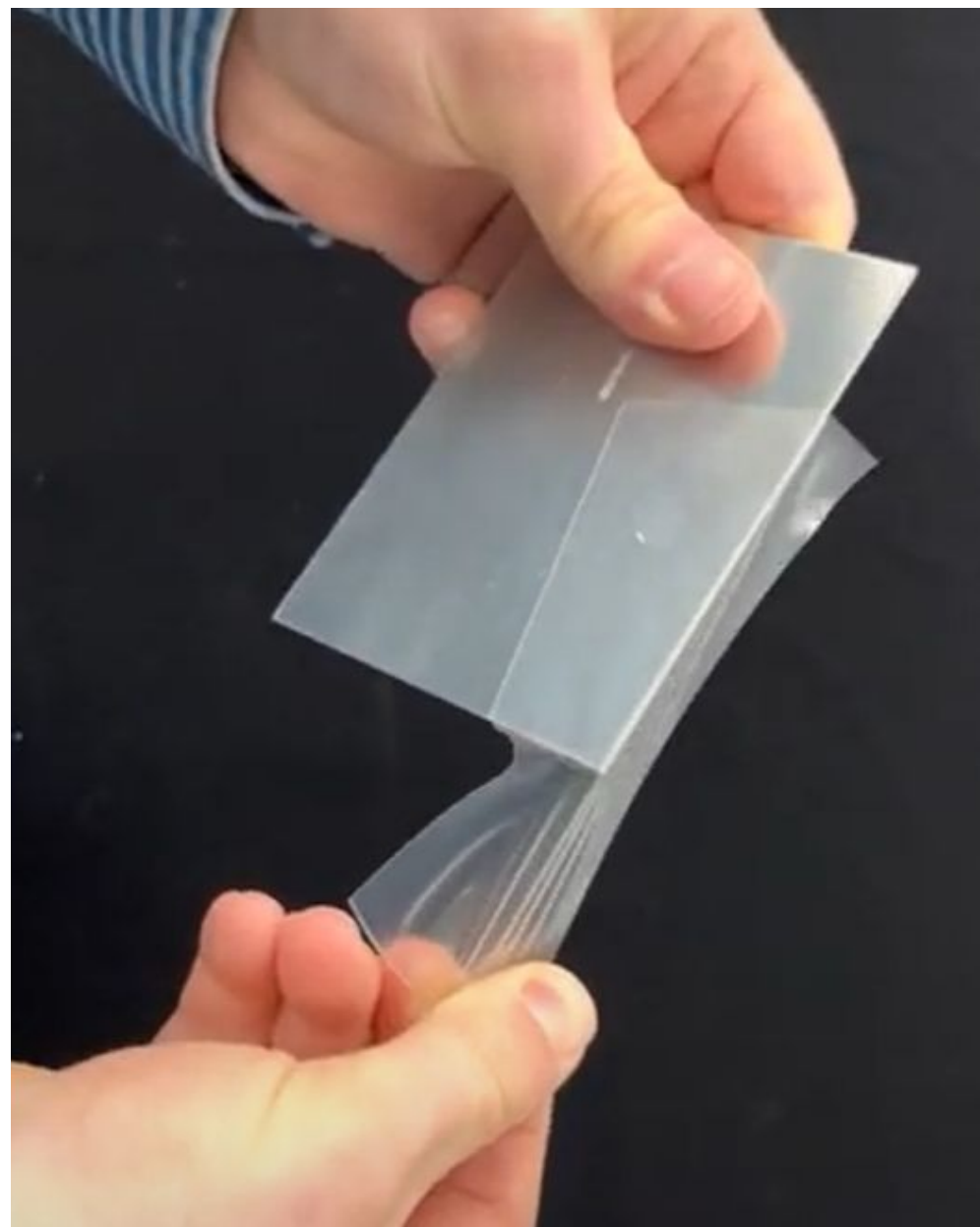
Flame-retardant version available

Maintain UL® 94V-0 within the battery pack

Problem to Solve: Mechanical Durability/Tear Resistance



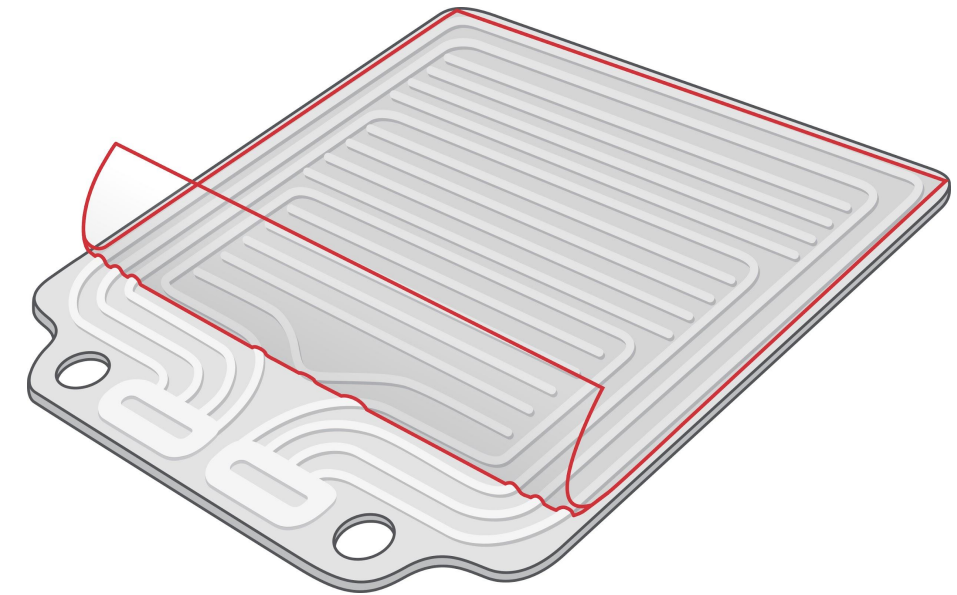
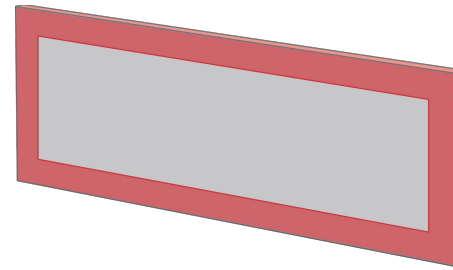
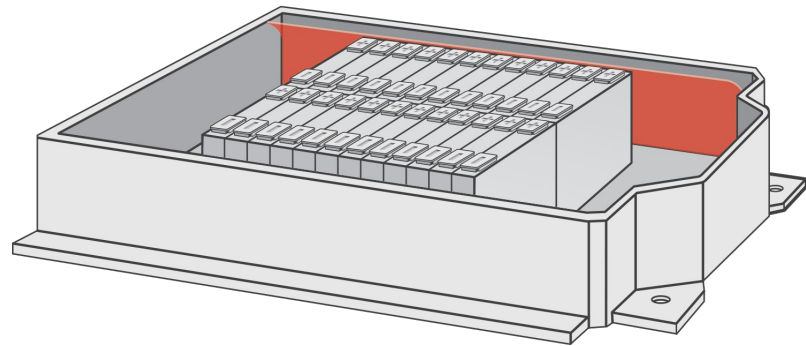
Solution for Corner Coverage: Conformable Dielectric



Volt Tough™ Tapes vs Spray Coatings

	Volt Tough Tape		Spray Coating	
Storage Requirements	**	Long shelf life, non-reactive chemistry	-	short shelf life and stricter storage requirements
Application Speed	**	Automatable	**	Automatable
Cure Speed	**	Instant cure	-	Requires ovens or UV cure station
Reworkability	*	Some repositionability	*	Can overspray pinholes
Plant Space Requirements	**	Small plant footprint	-	Coating and curing stations take up more space
Equipment Requirements	*	Often requires custom equipment, but do have standard applicators	**	Known equipment
Heat Flow	**	Thinner material helps with heat flow	*	Has to be thicker, which negatively affects heat flow
Dielectric Strength	**	Best in class	*	Requires thicker coating
Thinness	**	Can go down to 25 micron	-	Typically requires thicker coatings to reduce chance of pinholes
Corner Coverage	**	Designed to wrap around sharp corners	-	Can be challenging for some coatings
Quality Control	**	Visual systems easily integrated	*	Visual systems capable, but need to watch out for pin holes
Cost	**	Lowest cost in use	*	Varies greatly by chemistry and process type

EV Battery Applications for Boosting Dielectric Strength



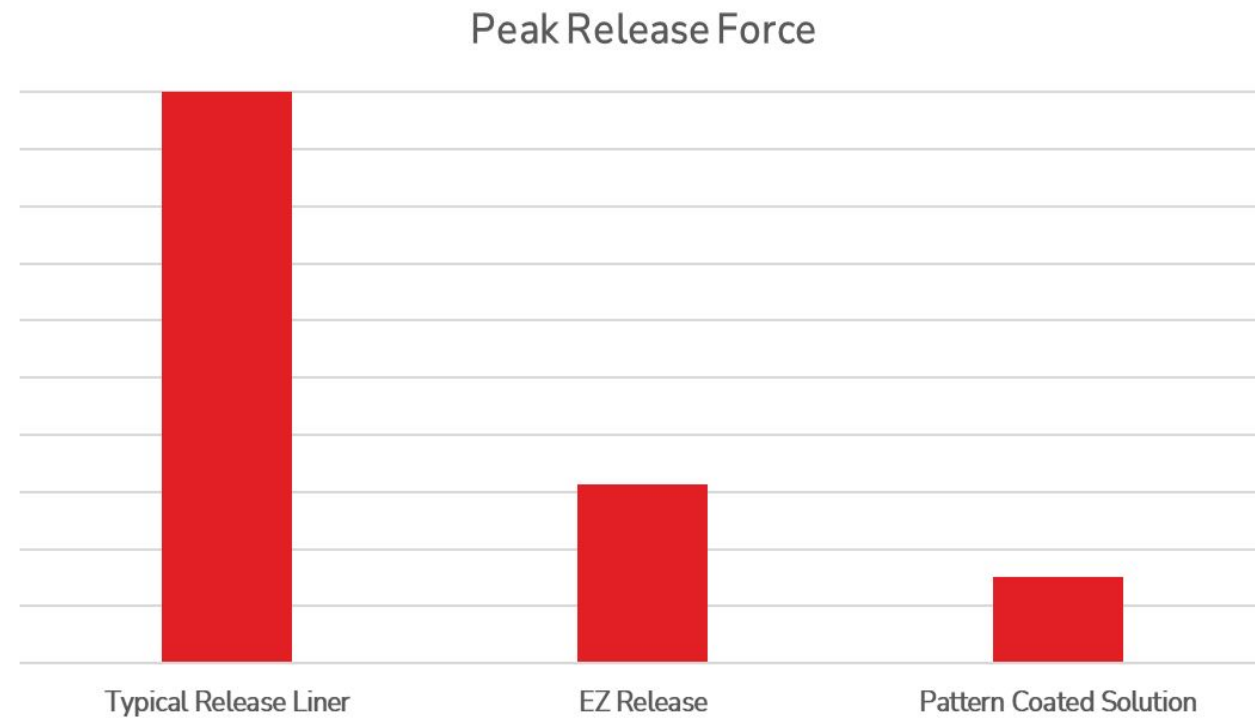
Application	Pack Structure			Cooling Plates or Ribbons		
	Flat Surfaces		Tear Resistant	Flat Surfaces		Conformable
Benefits	Economical	FR	Tear Resistant FR	Cost Effective Thin Profile	Flame Retardant Thin Profile	Conformable Tear Resistant
Name	FT0011	FT0065	FT0074	FT0012	FT0065	FT0074
Facestock(s)	Flame Tough™ PET	Flame Tough™ PET	Conformable	Volt Tough™ PET	Flame Tough™ PET	Conformable
Adhesive	Emulsion Acrylic	Flame Tough™ Acrylic	Acrylic	Acrylic	Flame Tough™ Acrylic	Acrylic
Total Thickness, mil (micron)	1.0 (25)	3.6 (92)	5.0 (125)	2.0 (50)	3.6 (92)	5.0 (125)
Dielectric Strength, kV	3.2	5.1	6.1	5	5.1	6.1
Notes	Clear, Linerless	White	Clear	Clear, Linerless	White	Clear

Design and Process Considerations

Optimizing for Assembly

Tuning Release Force

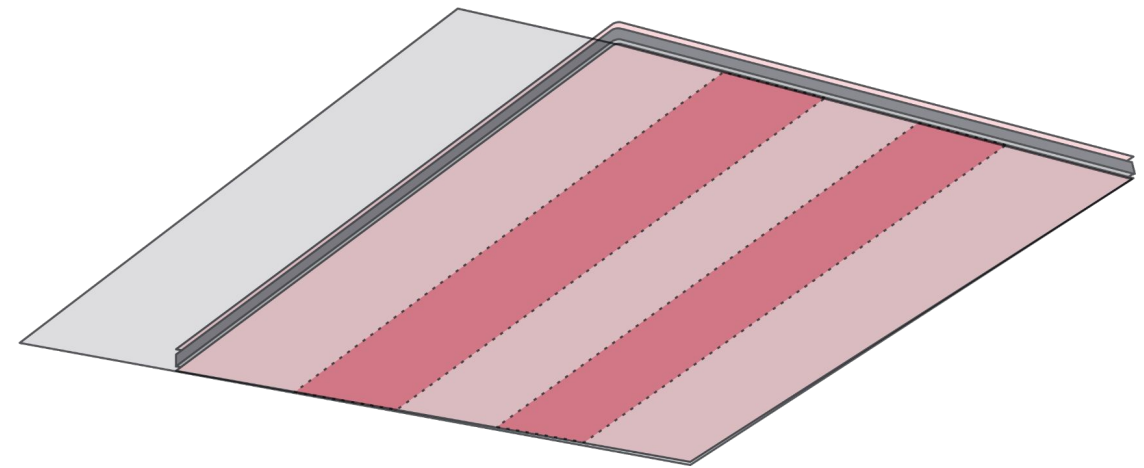
Avery Dennison reacts release chemistry inline and can tune release force to be lower, which can enable automation



Customization for Automation

Tapes can be pattern-coated and/or converted to have an extended liner to allow for automateable removal without tearing delicate insulation materials.

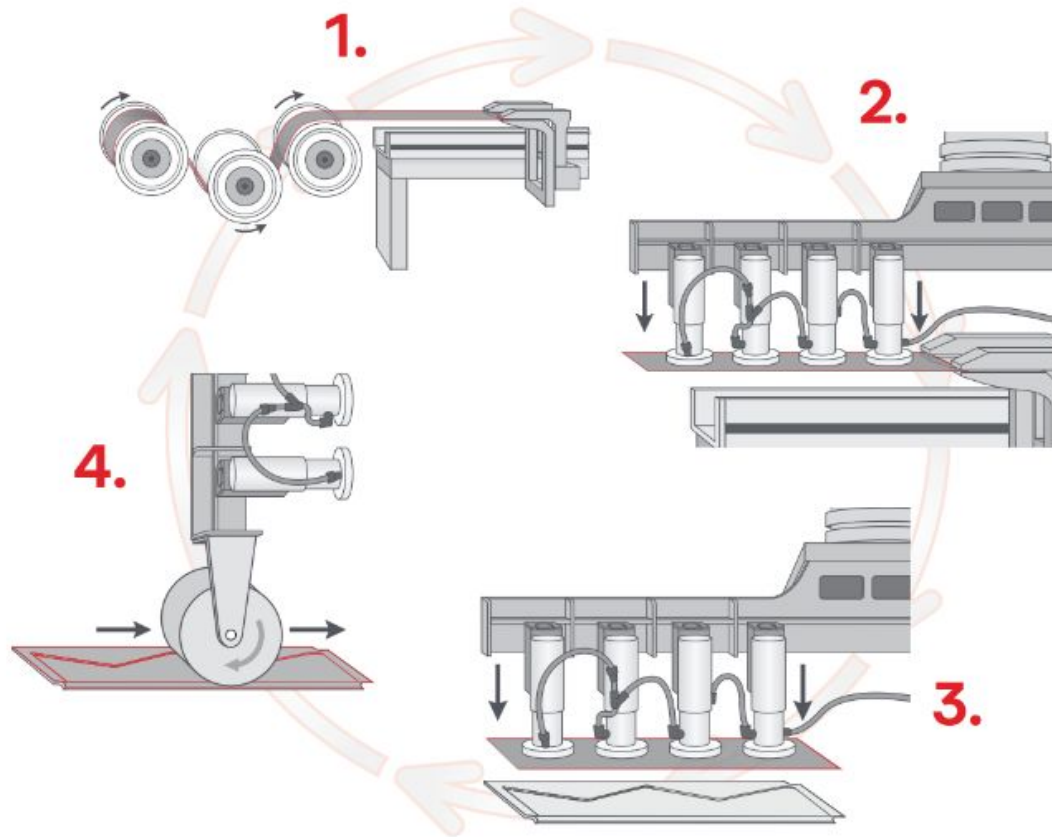
Bottom view



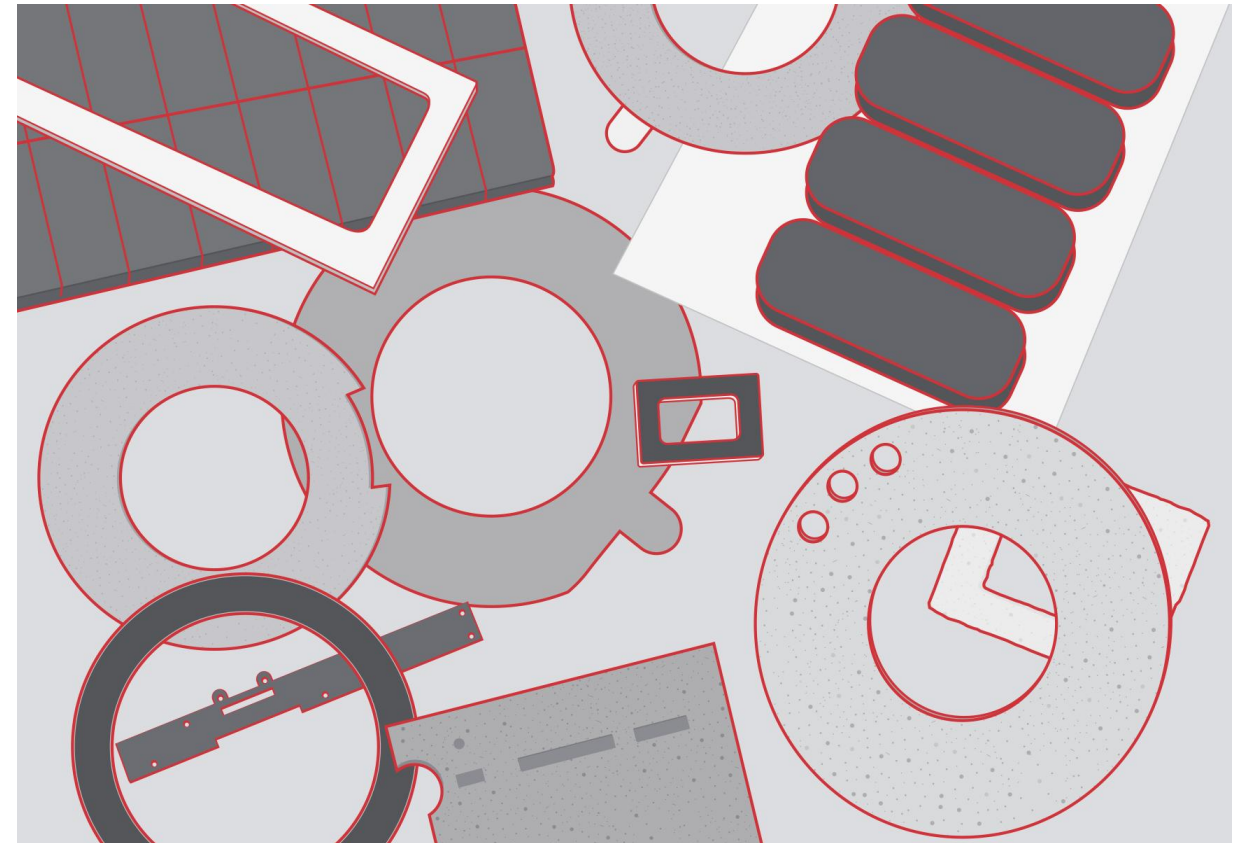
Manufacturing Considerations

Shape Complexity

Laminated and cut to length

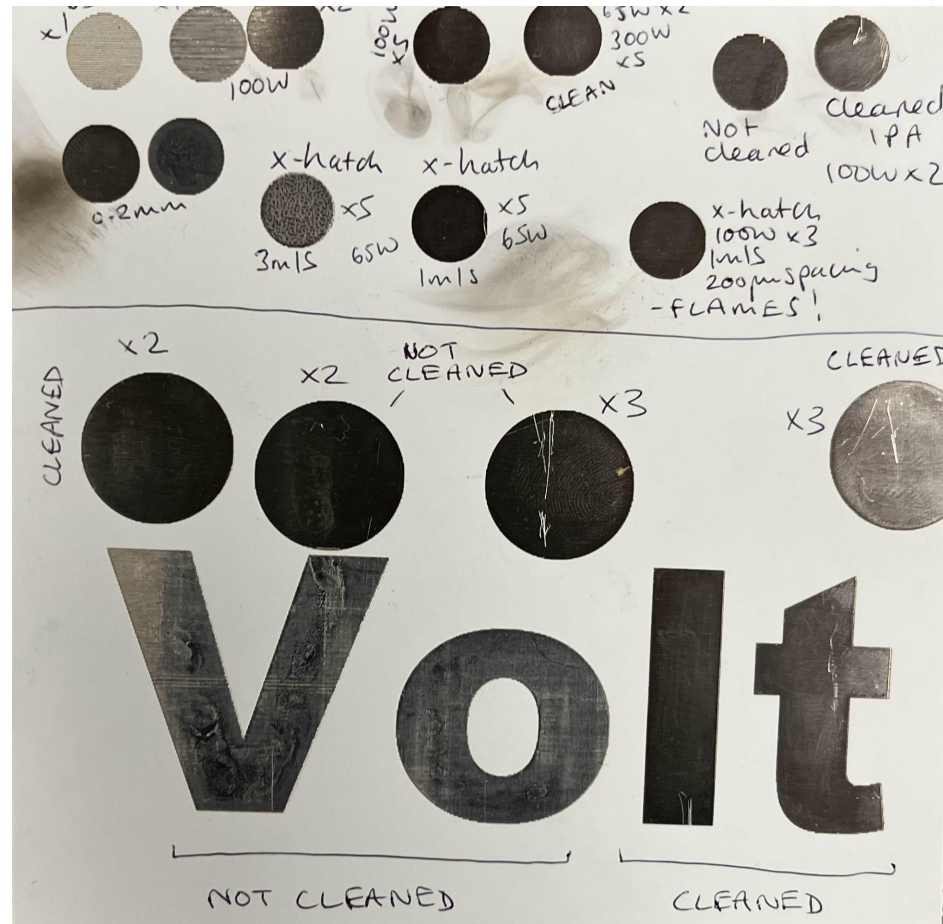


Die-cut to shapes and placed



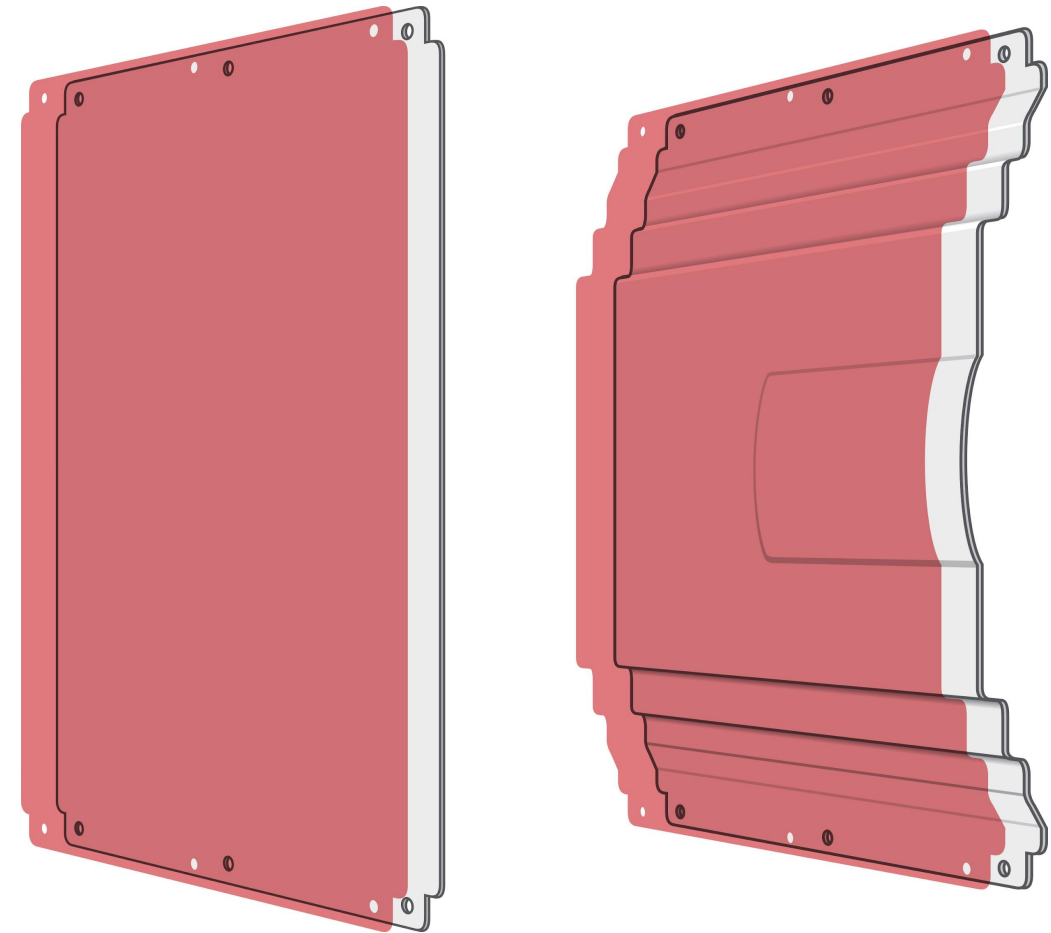
Finishing Considerations

Laser ablating off areas*



*Sample courtesy of Luxinar, Ltd.
run rate 1,134mm² per 15 seconds

Metal forming post lamination



Summary and Noteworthy Capabilities



Performance
Tapes

Capabilities and Support



Avery Dennison Performance Tapes prides itself by going beyond bonding to provide converters and end users with access to testing and collaboration with subject matter experts in order to offer solutions for your EV Battery applications.

Collaboration

- New product development for developing custom solutions for specific applications.
- Business development and specification support for emerging applications.
- Application engineering and technical support.

Testing Capabilities


- Flame performance testing at the tape and composite level.
- Dielectric strength testing at the tape and composite level.
- Traditional bulk property testing (peel, tack and shear).
- Environmental conditioning (temperature, humidity, UV, chemical and more).

New Electrical Insulation Design Guide

Avery Dennison
Performance Tapes
North America

EV Battery Electrical Insulation Design Guide

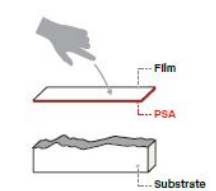
Optimize dielectric strength
with Avery Dennison
Volt Tough™ tapes



AVERY DENNISON | Performance Tapes

Avery Dennison
Performance Tapes
North America

A brief overview of PSA tapes



How PSA technology works

PSAs form a bond with a material upon contact under light pressure.


These adhesives have a wide range of applications, including the construction of high-performance tapes used across a wide range of industries. Tapes have a long history in the automotive, aerospace, building and construction, electronics, and general industrial segments.

PSA tape key performance factors

There is no "universal" PSA. Instead, product designers can choose from hundreds of adhesive formulations based on the needs of an application.

To facilitate that choice, we use three core performance factors to help quantify a tape's effectiveness.

- **Peel:** A measure of the force needed to remove an adhesive tape from a given substrate (which may be flexible, smooth, or rigid). Often the tape is pulled 180° or 90° from the substrate at a given speed.
- **Tack:** A measure of how fast the adhesive bond forms between two surfaces brought together under light pressure. It is a measure of the "instant stickiness" of the adhesive.
- **Shear:** Can be static or dynamic in nature. Static shear strength gives an idea of how long tape can hold a certain weight, whereas dynamic measures the force to pull apart in opposite directions. These tests measure the cohesive strength of the adhesive.



An adhesive must balance these factors for long-term stability and performance for a specific application.

Adhesives can also incorporate additives to modify their performance (for example, flame retardants, tackifiers, pigments, etc.).

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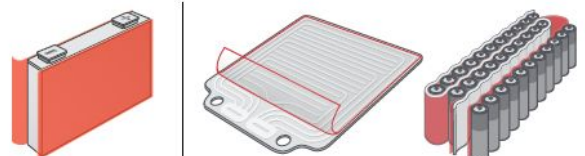
Avery Dennison
Performance Tapes
North America

Where and how to use Volt Tough™ dielectric tapes

Volt Tough™ tapes have a range of potential applications throughout a battery pack, including areas of the pack cover and throughout the pack's structure, cell housings, cells and cooling plates.

The tape can be laminated to the face of a component pre- or post-forming, used to wrap components, or used as a durable insulator for sharp metal edges.

Specific applications include cell wrapping and cooling plates or ribbons.



Application	Cell Wrapping		Cooling Plates or Ribbons			
	Single Wrap	Double-Sided	Flat Surfaces		Double-Sided	Conformable
Benefits	Flame-Retardant	Cost-Effective, Thin Profile	Flame-Retardant, Thin Profile	Flame-Retardant, Thin Profile	Bonds Cells, Automatable	Conformable, Tear Resistant
Name	FT 0066	FT 0012	FT 0011	FT 0066	FT 0066	FT 0074
Facestock	Flame Tough™ PET	Volt Tough™ PET	Volt Tough™ PET	Flame Tough™ PET	Flame Tough™ PET	Conformable
Adhesive	Flame Tough™ Acrylic	Acrylic	Acrylic	Flame Tough™ Acrylic	Flame Tough™ Acrylic	Acrylic
Total Thickness, mil (micron)	3.6 (92)	2.0 (50)	1.0 (25)	3.6 (92)	7.0 (178)	5.0 (125)
AC Dielectric Strength, kV	5.1	5.0	3.2	5.1	9.0	6.1
Notes	White	Clear, Linerless	Clear, Linerless	White	White, Double-Sided	Clear

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9

Contact Information

For more information, please contact:

Max VanRaaphorst
Avery Dennison Performance Tapes
BDM E Mobility and Automotive

Email: max.vanraaphorst@averydennison.com

And visit tapes.averydennison.com/evbattery



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A