Avery Dennison
Performance Tapes
White Paper

North America

Stampable Dielectric Tape Solutions for Battery Packs

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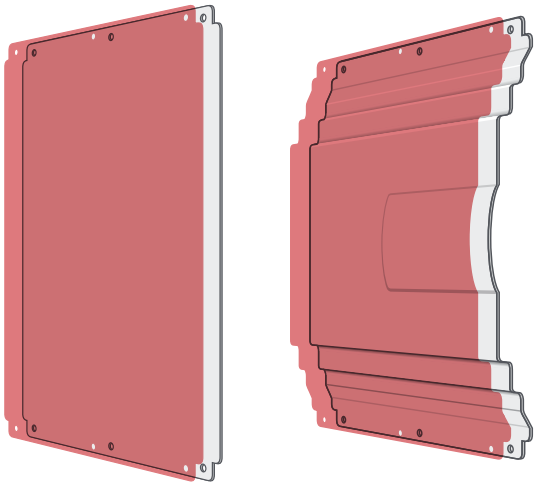


Executive Summary

As part of their efforts to provide greater electric vehicle (EV) performance and range, EV battery manufacturers have been increasing pack voltage and overall energy density. These increases, however, have prompted the search for more robust and cost-effective dielectric protection solutions to prevent arcing and other electrical failures.

Multiple solutions *are* available, including dielectric coatings and pressure-sensitive adhesive (PSA) tapes with various dielectric film facestocks, including PET film. Dielectric coatings have enjoyed an advantage, especially with complex-shaped parts, due to their ability to conform closely to those shapes. PET-based tapes tend to be best suited for flat surfaces.

Now, new technology — PSA tape featuring a stampable dielectric protection solution — promises to change EV battery manufacturers' approach to dielectric protection. This white paper will demonstrate how this solution offers performance superior to coatings from a battery design and manufacturing process perspective.

Part I: Dielectric protection in EV battery packs

Prevention of electrical arcing in EV battery packs is critical

The evolution of EV battery pack voltage and energy density has been pivotal in enhancing vehicle performance and range.

Today's EVs utilize battery packs operating at 400V or 800+V. This enables faster charging times and more efficient power delivery to the motor. Concurrently, improvements in energy density — the amount of energy stored per unit of mass or volume — have allowed for lighter, more compact battery packs that can store more energy.

Prevention of electrical arcing has always been a core safety concern in battery pack design. With this growth in pack performance, however, prevention has become imperative to prevent short circuits; thermal runaway; or electrical hazards for the driver, passengers, and service technicians.

An overview of traditional dielectric protection solutions

Robust, cost-effective dielectric protection solutions are thus needed, and EV battery manufacturers have employed a variety of methods. The most common are dielectric coatings (applied by spraying or dipping), or PSA tapes utilizing dielectric films such as PET or polyimide.

These coatings and tapes can be applied to the internal components of a battery pack to prevent unintended electrical conduction. They ensure battery packs can operate effectively in diverse conditions, improving their performance and longevity, and enhancing driver and passenger safety.

Dielectric coatings have enjoyed an added advantage over film tapes due to their ability to be easily applied to stamped metal parts with complex geometries. As manufacturers continue to evolve their designs, conformability has become an increasingly important requirement for dielectric materials.

Shortcomings of traditional conformable dielectric solutions

Dielectric coatings can indeed be effective electrical insulators in modern EV batteries, and they are highly appealing due to their conformability. However, these coatings do have shortcomings that can affect the manufacturing process and the overall effectiveness of the battery pack design.

Design shortcomings	**Restrictive thickness**	Coatings often need to be applied thickly to prevent pinholes and allow uniform coverage for dielectric protection. This thickness restricts space in the pack for other materials.
	Inhibited heat flow	Thickly applied coatings may inhibit heat flow across the battery's cooling components.
Manufacturing process shortcomings	**Multiple steps required**	Multiple steps are needed for part cleaning, and applying and curing of the coating.
	Significant physical footprint	Significant floor space is needed for cleaning, applying and curing equipment.
	Slow speed	Significant time is needed for cleaning, applying and curing.
	High scrap rate	Coating errors require parts to be reworked or scrapped, driving costs and reducing profitability.
	Sub-optimal workflow	Most coatings require application after the part is formed or stamped to prevent cracking or damage. This may result in a sub-optimal workflow.
	Significant costs	An in-house coating process requires a significant capital investment. A manufacturer may choose to outsource coating to a third-party vendor, but that will result in significant service fees and added logistical complexity.

Better conformable dielectric solutions are needed that allow manufacturers to avoid these shortcomings. PSA tapes with stampable dielectric films, designed to be stamped and formed with their underlying substrates, are just such a solution.

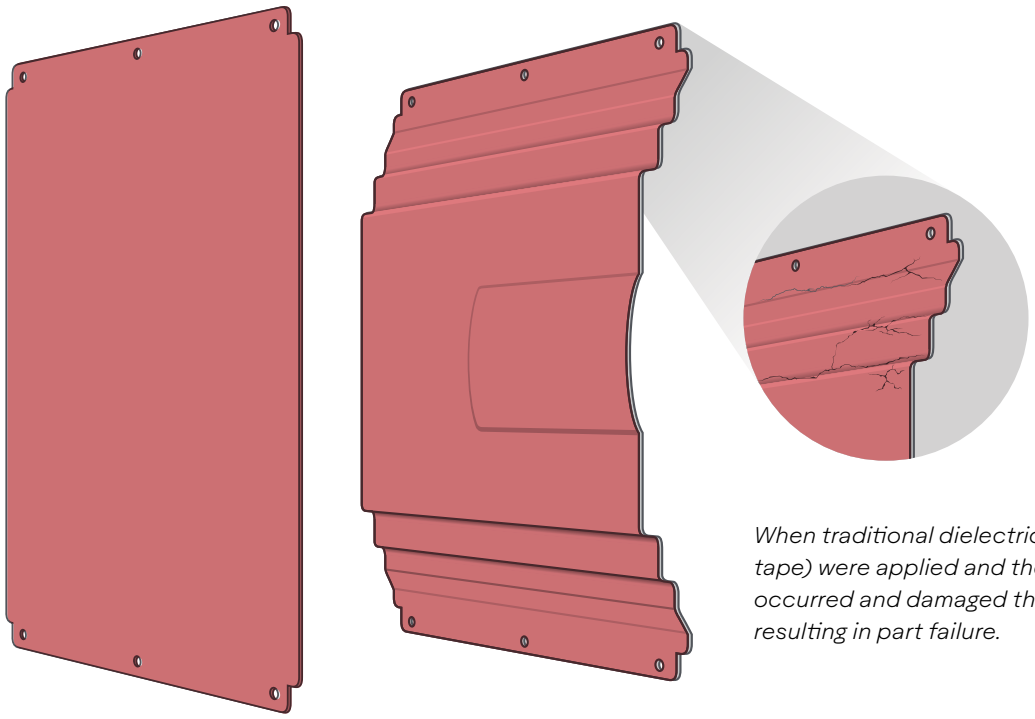
Part II:
A stampable dielectric protection solution

Evaluating stampable dielectric tapes against competing dielectric technologies

A new type of PSA tape technology is now available that addresses these shortcomings. This tape features a highly conformable dielectric film facestock that is fully compatible with metal stamping processes.

The tape can be applied to a metal blank (manual or automated application process), then stamped along with the blank. The result is a formed metal part with dielectric protection already applied. Unlike coatings, the PSA tape and its conformable dielectric film resist damage or cracking in the press.

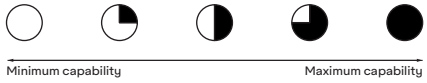
In testing completed at the Avery Dennison Performance Tapes laboratory, an ISO-9000 facility, samples of a PSA-based dielectric protection solution were applied to aluminum sheet metal blanks. The samples were then stamped to test the durability of the tape under various pressures typical of industrial metal stamping. In all cases, the PSA solution withstood applied pressures, even in extreme instances when sufficient pressure was applied to crack the aluminum substrate.



When traditional dielectric solutions (coatings or PET tape) were applied and then stamped to shape, cracking occurred and damaged the dielectric protection layer, resulting in part failure.

Here's how this new technology compares to traditional dielectric solutions.

Technology	Apply prior to stamping/ forming	Conformable to complex parts/shapes	Dielectric strength	Facilitates heat flow	Minimal equipment footprint	Tear/crack resistance
PET tape	○	◔	●	●	●	○
Polyimide tape	○	◔	●	●	●	○
Powder coating	○	◕	◑	◑	○	◔
UV coating	○	◕	◕	◑	○	◔
Stampable dielectric PSA tape	◕	◕	●	●	●	◕



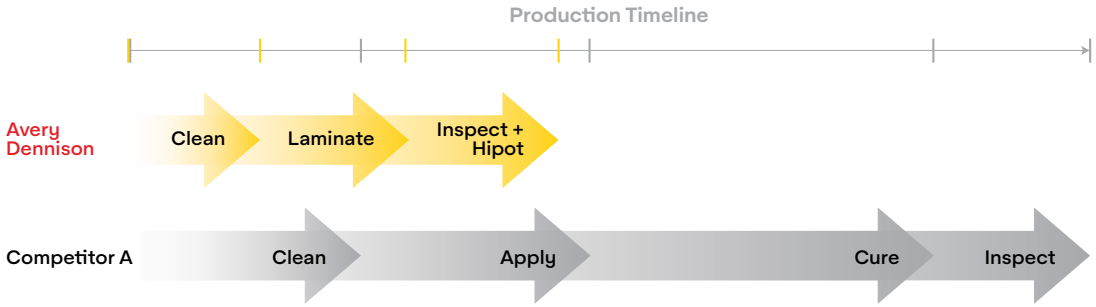
Challenge: Workflow optimization and waste reduction

Dielectric coatings typically must be applied only after a part is stamped or formed, limiting an assembly line's flexibility. Coatings sometimes have to be applied twice to ensure sufficient thickness for the required dielectric strength. Errors in the coating process often result in parts being completely scrapped, increasing waste and driving cost.

PET or polyimide tapes, meanwhile, are typically die cut, then applied to a finished metal part using unique tooling. This process can add cost and complexity.

Solution: Stampable dielectric PSA tape can be applied either manually or with automated equipment, without complex die cutting, and before part stamping or bending. Application errors can be addressed immediately and are usually solved by simply repositioning the tape.

This approach allows a manufacturer to increase the efficiency of its assembly line through a less labor-intensive process and lower scrap rates, and, as a result, increase its production rates.



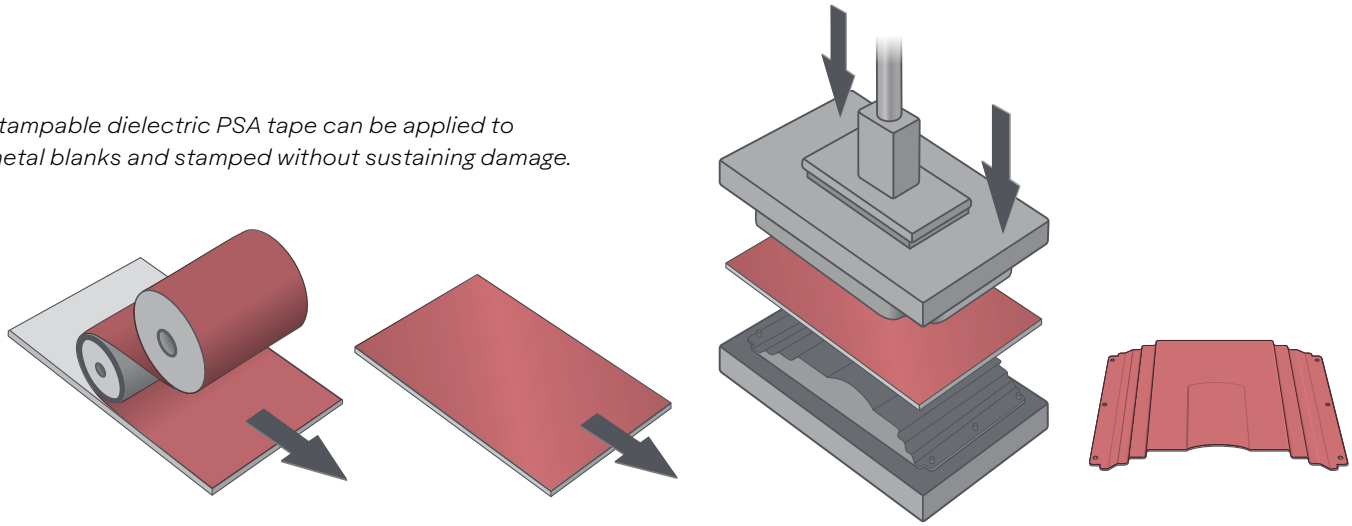
Stampable dielectric PSA tapes are easy to handle and apply with manual or automated methods. This ease of use can help a manufacturer improve productivity.

Challenge: Conformability to complex parts/shapes

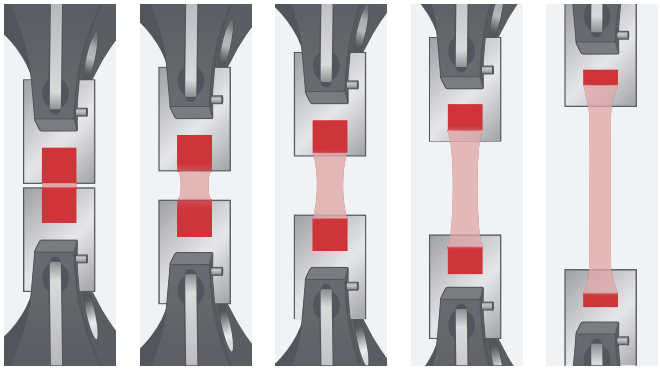
PET- and polyimide-based dielectric tapes are useful for flat parts that are not stamped or formed into curved/complex geometries. But they are liable to tear on corners or burrs, and cannot withstand forces applied during stamping. Coatings conform closely to complex geometries. But they also tend to chip or crack if stamped.

Solution: Stampable dielectric PSA tape can be applied directly to sheet metal blanks then stamped/formed with the blank, conforming to the part's geometry without being damaged in the stamping process.

Stampable dielectric PSA tape can be applied to metal blanks and stamped without sustaining damage.



These stampable tapes combine high elongation at break and high tear resistance. This allows it to stretch with sheet metal without rupturing, tearing or cracking. It also can be reliably applied to corners and metal burrs with minimal risk of damage to the tape.

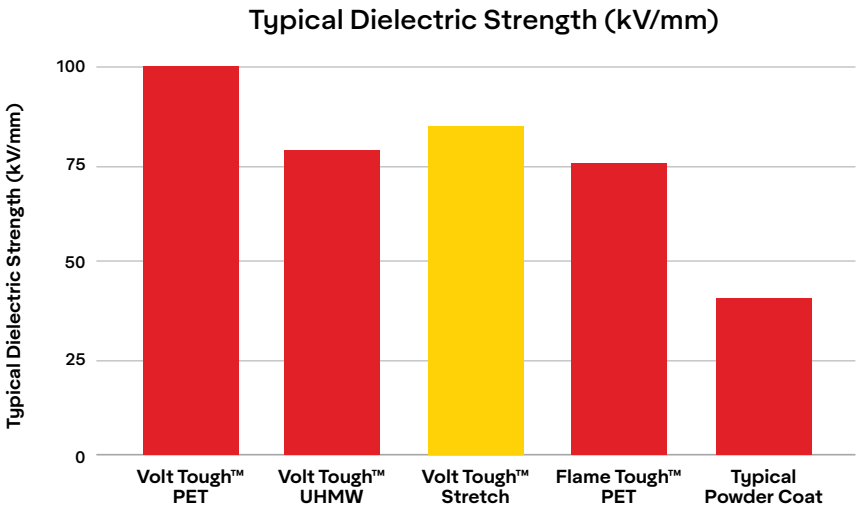


PSA-based dielectric solutions are engineered for high elongation at break combined with high tear resistance.

Challenge: Dielectric strength

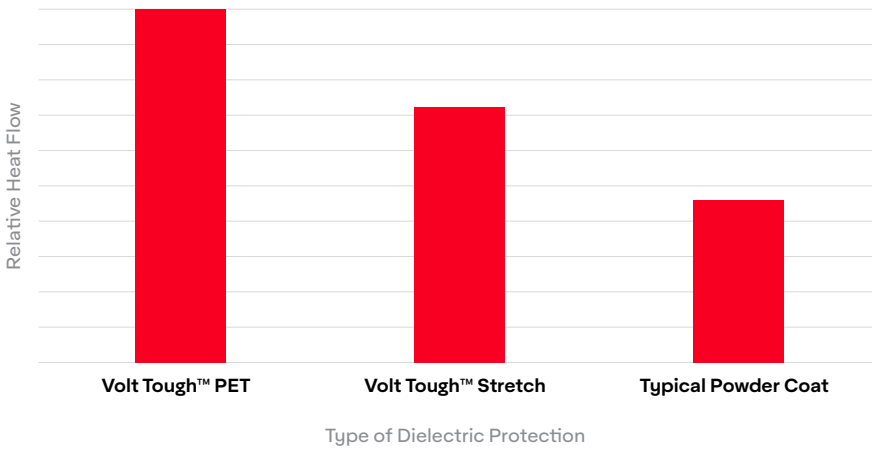
To achieve the required dielectric strength, dielectric coatings typically need to be applied with significant thickness. This limits space within a battery pack for other materials, inhibits heat flow and lowers pack energy density.

Solution: Stampable dielectric PSA tape provides significantly more dielectric strength per unit of thickness compared to a typical dielectric coating.



Avery Dennison dielectric tapes, such as those in its Volt Tough™ portfolio, provide greater dielectric strength per unit of thickness than typical dielectric coatings.

A thinner dielectric solution provides manifold benefits. It allows more space for batteries, increasing pack energy density. It allows more space for other functional materials, such as those designed to mitigate thermal runaway. It also allows more effective heat flow throughout the battery pack, including across cooling components.



Avery Dennison dielectric tapes offer less resistance to heat flow compared to powder coating.

Challenge: Minimal equipment footprint

The application of a coating-based dielectric solution — including part cleaning, application, and curing — typically requires a significant amount of capital equipment expenditure and a correspondingly large physical footprint.

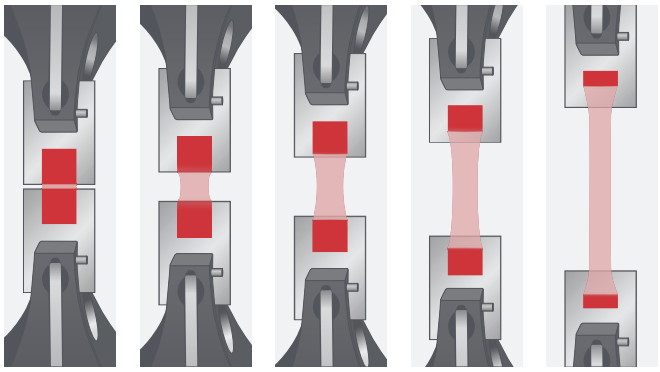
Alternatively, a manufacturer can opt to outsource the coating process. But this brings its own set of challenges, including processing/material fees, shipping costs and added logistical complexity.

Solution: A PSA-based dielectric protection solution can be applied in-house with manual or automated processes. In either case, the physical footprint needed for tape application is significantly less than what is required for coating application. PSA tape application equipment tends to require a lower capex than coating equipment.

Challenge: Tearing and cracking resistance

Polyimide and PET tape dielectric solutions, which can tear easily, typically provide poor performance around metal corners and edges. Neither product is engineered to stretch significantly.

Solution: PSA-based dielectric protection solutions have very high elongation at break combined with high tear resistance. The combination of these properties allows it to stretch with sheet metal without rupturing, tearing or cracking. The product also can be reliably applied to corners and metal burrs with minimal risk of damage to the tape.



PSA-based dielectric solutions are engineered for high elongation at break combined with high tear resistance.

Part III: Introducing Next-Generation Volt Tough™ Stretch

A PSA-based stampable dielectric solution from Avery Dennison

Avery Dennison has developed and introduced a PSA-based dielectric protection solution. Part of the company's Volt Tough™ portfolio, this tape is the next generation of the Volt Tough™ Stretch PSA dielectric tape (Avery Dennison part number FT 0031).

This solution is designed to accommodate a wide range of needs while addressing key challenges for electrical insulation in battery packs. Importantly, this new tape solution is highly compatible with metal stamping processes and other metal-forming techniques.

Put simply, next-generation Volt Tough™ Stretch can be applied to a metal blank, then stamped into a complex shape without significant risk of the tape cracking, tearing, or sustaining any other type of damage.

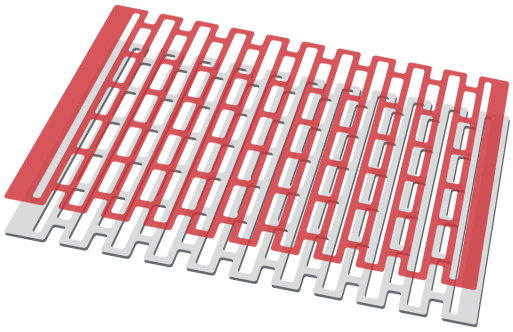
Like all PSA tapes, next-generation Volt Tough™ Stretch is easy to apply and reposition, features a thin profile, and is durable for the life of the battery.

Features	Benefits
High dielectric strength (AC) ~11.0 kV Tested for breakdown voltage and dielectric strength requirements using GB/T 1408.1-2016 and ASTM D149 and D3755 test methods	Excellent dielectric performance; easily outperforms coatings of equal thickness
Pure-acrylic adhesive	Provides an excellent bond to battery pack components, high shear strength and high heat resistance
Opaque blue	Facilitates camera system detection
Proprietary, stretchable facestock	Facilitates manufacturing efficiency and design effectiveness by stretching easily around unique geometries and burrs while being tear-resistant
Can be stamped and formed without sustaining damage	Eliminates post-processing steps associated with coatings (including masking), resulting in lower costs and facility space savings

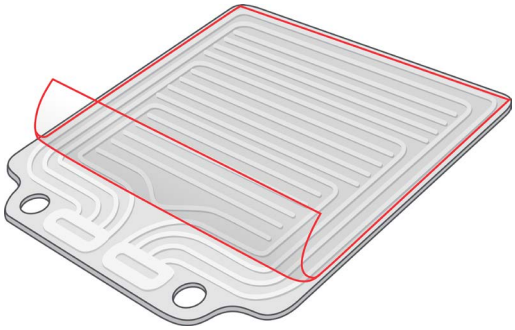
Applications

Next-generation Volt Tough™ Stretch can be used for bonding and protection in various applications throughout a battery pack. It has been increasingly used with cooling plates and pack structures.

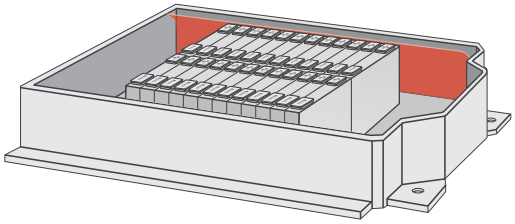
- Pack structural components
- Flexible and rigid busbar and cell connection systems in EV battery assemblies
- Various cooling components, including chill plates and cooling ribbons



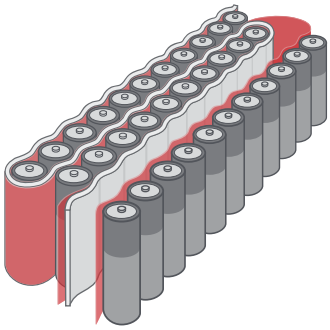
Busbar / Cell Connection Systems



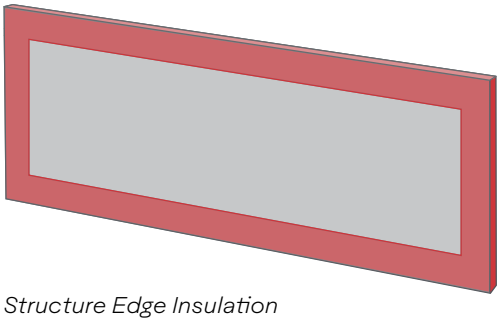
Cooling Plate



Pack Structure



Cooling Ribbon



Structure Edge Insulation

Part IV: Proposed Use Cases & Outcomes

The case for next-generation Volt Tough™ Stretch

Avery Dennison prepared a hypothetical case study to help illustrate, in broad terms, the advantages of using its stampable dielectric protection solution, next-generation Volt Tough™ Stretch. This proposed scenario uses estimated values for cost and other relevant factors. Actual results may vary based on the business, its rate of part production and other factors.

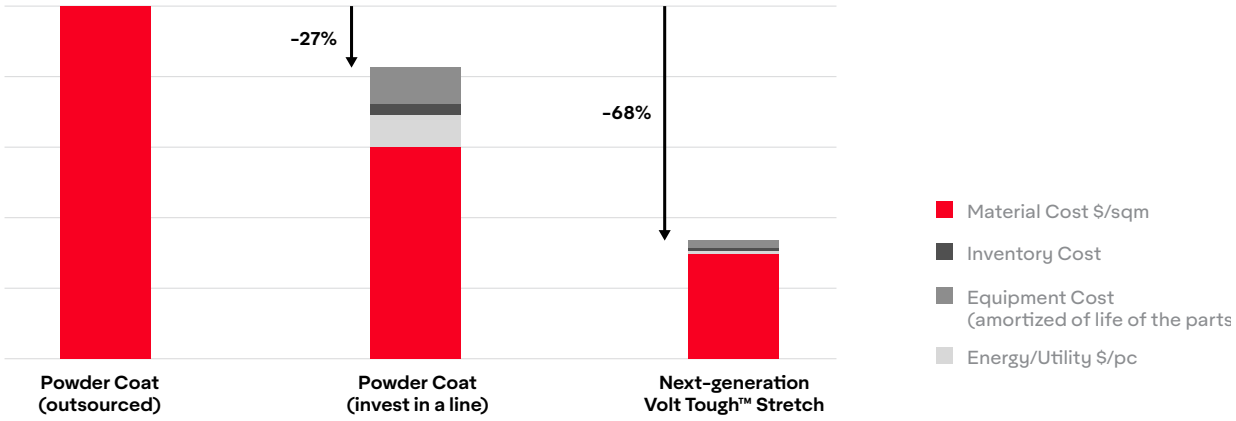
Example 1: Cooling ribbon for side-cooled cylinder cells

This example considers the application of dielectric protection to EV battery cooling ribbons, comparing three approaches:

- Coating applied post-stamping, off-site by a third-party vendor (outsourced).
- Coating applied post-stamping, on-site by the manufacturer. This requires capital investment in powder coating equipment.
- Automated application of next-generation Volt Tough™ Stretch after brazing of the spigots and pre-stamping. This requires capital investment in PSA application equipment.

The comparisons assume a 200,000 vehicle-per-year model across five years of production. Prices to the incumbent are normalized.

Relative Piece Price Cost by Dielectric Technology



Results:

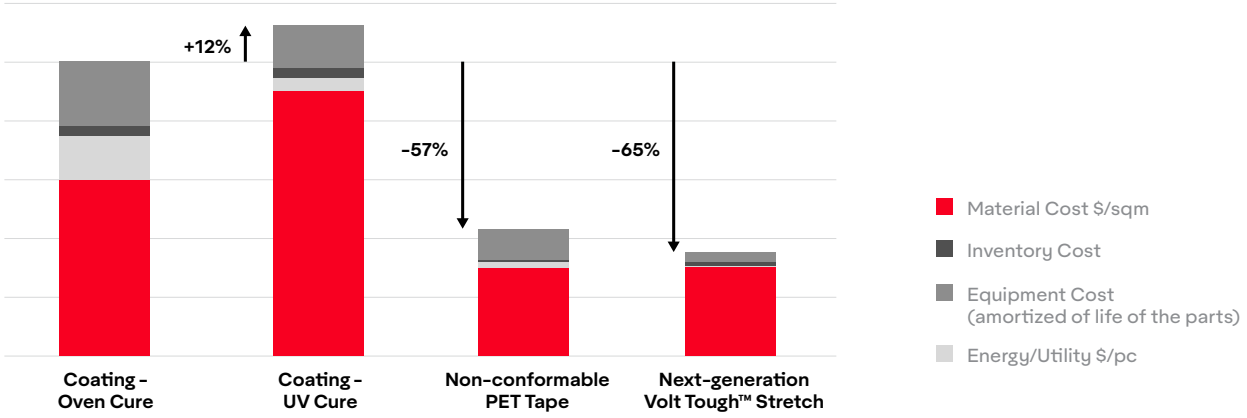
1. Outsourcing puts the variable cost burden on the third party, but can lead to the highest piece price cost due to third-party margin and logistical costs.
2. Volume is high enough for the company to invest in an in-house powder coating line. However, the company assumes significant risk if it has never powder coated before. Additionally, if capital for the powder coating line is tied to that single part, there's a significant risk to the line's amortization cost if part production decreases.
3. Next-generation Volt Tough™ Stretch allows for greater simplicity and lower cost. The fast adhesion of the PSA means parts can be produced in a one-piece flow. A vision system and/or hipot can ensure 100% part compliance prior to and/or after forming steps.

Example 2: Module cover

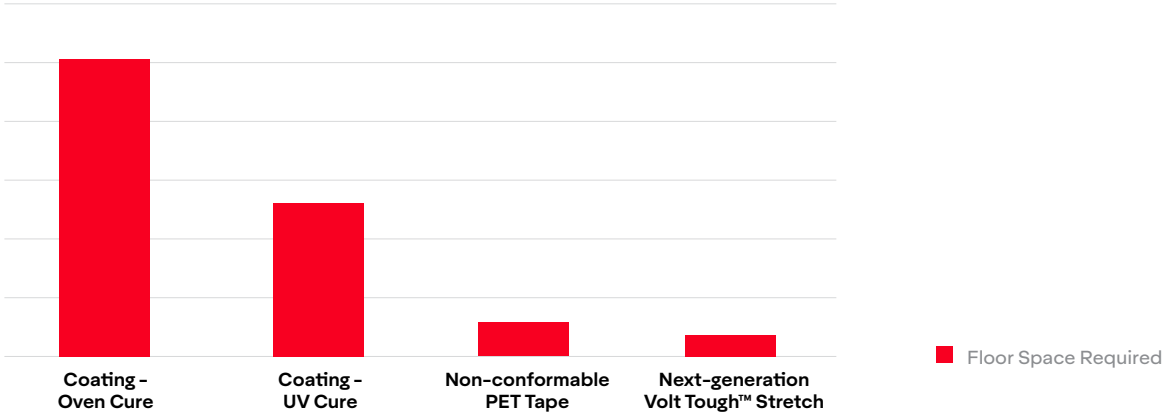
This example considers the application of dielectric protection to EV battery module covers, comparing four approaches:

- Coating applied on-site and oven-cured, post-stamping, by the manufacturer. This requires capital investment in coating equipment.
- Coating applied on-site and UV-cured, post-stamping, by the manufacturer. Again, this requires capital investment in coating equipment.
- Automated application of a non-conformable PET tape
- Automated application of next-generation Volt Tough™ Stretch after brazing of the spigots and pre-stamping. This requires capital investment in application equipment.

Relative Piece Price Cost by Technology



Relative Floor Space Requirements by Technology



Results:

1. Both coating processes have higher relative material costs. Even if the coating line is utilized for other parts, it still has significant secondary costs with energy and amortization of the equipment.
2. The UV cure process offers some flexibility in curing and plant footprint. However, care is needed to minimize overspray. A two-pass, two-cure process may be needed to reduce the likelihood of pinholes.
3. PET tapes are not compatible with the stamping process. They instead need to be die cut to shape and applied post-stamping, typically using unique tooling and automation. This adds cost and complexity. It also creates a higher risk of failures due to its lack of tear resistance.
4. Partly because it can be applied to metal blanks (pre-formed), next-generation Volt Tough Stretch™ requires significantly lower-cost lamination equipment. That equipment also requires significantly less floor space.
5. While next-generation Volt Tough Stretch™ has a slightly higher material cost than PET tapes, its simpler processing and application requirements reduce its total cost relative to the PET tape option.

Conclusion

In all cases, next-generation Volt Tough Stretch™ dielectric film tape is the superior choice when compared to coating or other tape options.

Again, this is a hypothetical case study based on estimated values for costs and other factors. Avery Dennison welcomes the opportunity to perform customized analyses for manufacturers in the EV battery industry.

Part V: Avery Dennison solutions for EV battery manufacturing

The Avery Dennison EV Battery portfolio

The Avery Dennison EV Battery portfolio includes various functional bonding and protection tapes built on multiple PSA technologies. These are engineered to make EV batteries safer, more efficient and easier to assemble.

The portfolio can help manufacturers solve some of the most common challenges in battery design and construction, including reducing flammability, boosting dielectric strength and design/assembly optimization.

Beyond bonding

Avery Dennison Performance Tapes offers extensive support beyond its product portfolio. This includes providing converters and end users with access to testing and collaboration with subject matter experts to develop unique solutions for EV Battery applications.

Collaboration	Testing capabiliites
New product development for creating custom solutions for specific applications	Flame performance testing at the tape and composite level
Business development and specification support for emerging applications	Dielectric strength testing at the tape and composite level
Application engineering and technical support	Traditional bulk property testing (peel, tack and shear)
	Environmental conditioning (temperature, humidity, UV, chemical and more)

Summary: A conformable dielectric tape solution

EV battery pack voltages are increasing, resulting in greater pack energy density and improved vehicle performance. With this increase, however, comes a greater need for dielectric solutions that are not only reliable and durable, but complement modern pack design and the needs of manufacturing processes.

The Avery Dennison Volt Tough™ Portfolio of dielectric PSA tapes for EV batteries addresses these needs. The next-generation Volt Tough™ Stretch offering provides manufacturers with a dielectric solution that's stampable, conformable, resistant to tearing, and accommodates the heat flow needs within the pack.

Contact Avery Dennison to learn more

If you're an OEM, automotive tier supplier or converter representative looking to better understand the potential for PSA tapes in EV batteries, please contact us directly at dustin.winter@averydennison.com or max.vanraaphorst@averydennison.com.

To learn more about Avery Dennison Performance Tapes' solutions, visit www.tapes.averydennison.com/evbattery.

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