Avery Dennison
Performance Tapes
White Paper

North America

Considerations When Selecting Pressure-Sensitive Adhesive Tapes for Use With Mica in EV Batteries

An Avery Dennison White Paper

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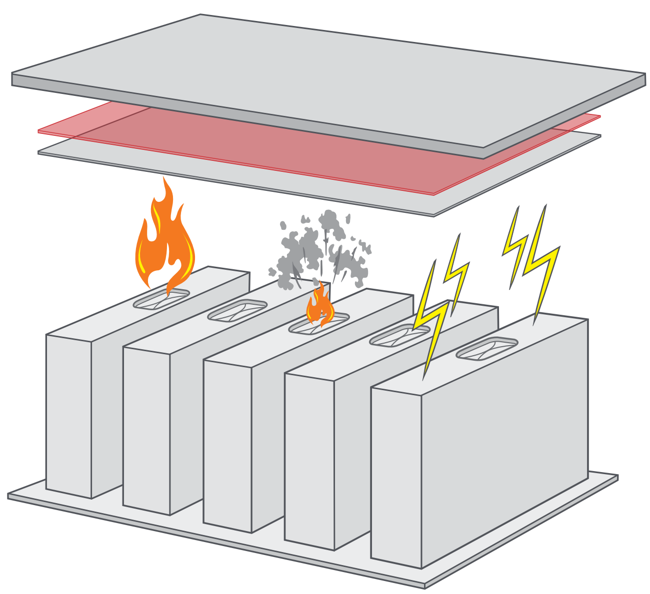
Created with support from Asheville Mica Energy Solutions.

Introduction

The EV battery industry is evolving rapidly, pushing the need for advanced materials that are thinner, lighter and safer. Engineers are increasingly turning to mica as a material solution that helps improve vehicle reliability and safety by containing thermal runaway. Pressure-sensitive adhesive (PSA) tapes, meanwhile, have emerged as a preferred solution for bonding mica materials in a battery pack.

This paper will explore a common challenge associated with using PSA tapes with mica. Referencing laboratory data, it will provide guidance to engineers and others involved in the design and assembly of these materials.



Engineers are turning to mica as a material solution to prevent thermal runaway in EV batteries. Mica can be bonded into place using PSA tapes.

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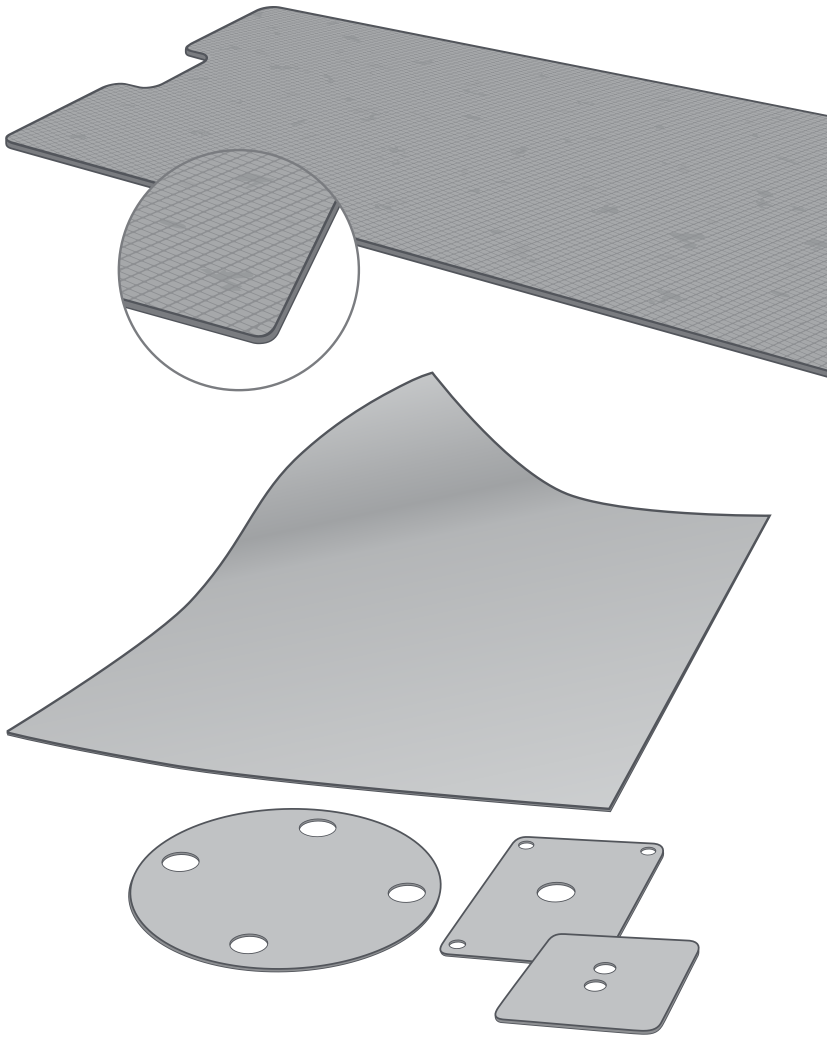
Mica is effective and versatile for thermal runaway protection

Mica laminates and composites are excellent choices for thermal runaway protection. They meet the UL® 2596 industry standard for thermal and mechanical performance properties of EV battery enclosure materials. This standard features a torch and grit (TaG) particle test simulating a thermal runaway event with discharge of inorganic and metal parts from a battery with sufficient velocity to puncture additional batteries.

Mica also offers a high degree of design flexibility. It can be manufactured as thin, flexible sheets for use around curved surfaces or as rigid cut parts for assembly within a pack. These materials may appear throughout an EV battery: above cell barriers, between cells, on the underside of the lid, between modules, or wrapped around specialty parts.



Mica can be manufactured as thin, flexible sheets, or as thicker, rigid sheets that can be die-cut into various shapes.

PSA tapes offer many advantages for EV batteries

Reliable and versatile PSA tapes can be either a primary solution or an accessory bonding method for functional materials in EV batteries and other electrified vehicle components. They offer a range of benefits for pack design and assembly including:

- **Safety:** PSA tapes require no special hazardous material handling protocols.
- **Assembly optimization:** PSAs provide virtually immediate green strength with cure time measured in microseconds rather than hours or days. Tapes can also hold parts in place while a pack is assembled.
- **Consistency:** PSAs offer consistent thickness upon application. Each battery pack coming out of assembly will have the same amount of adhesive as every other pack.
- **Versatility:** PSA tapes can be laminated to foams, fibers and films, and die-cut to specification. Adhesives can be engineered with properties that enhance their ease of use (such as easy removability/repositionability), long-term durability and flame resistance.

The challenge of using mica with PSA tapes

Combined, mica and PSA tapes offer many advantages to battery pack designers. However, the property of mica that makes it an excellent thermal runaway prevention material may also present a particular challenge during mounting and assembly with PSA tapes.

Mica is a platelet ceramic microstructure with weak interlaminar forces. Mica surfaces thus have a “flaky” and somewhat delicate texture. A strong adhesive may cause such a surface to delaminate when subjected to moderate or high shear forces. More specifically, the removal of a PSA tape’s protective silicone liner during part assembly may provide enough shear force to delaminate the underlying mica surface.

For this reason, those manufacturing mica materials with integrated PSA tapes should make careful consideration of several factors.

Trials overview

To help explain these factors, we conducted a series of laboratory trials in the Avery Dennison Performance Tapes Innovation Center, an ISO 9001- / ISO 17025-certified facility in Painesville, Ohio.

These trials involved samples of various PSA tapes and mica solutions used in EV battery manufacturing.

- Tapes included those available from the Avery Dennison EV Battery Portfolio. Avery Dennison is a leading supplier of PSA tape products to a wide range of global industries, including automotive.
- Mica laminate and composite materials were provided by Asheville Mica Energy Solutions, a global supplier of mica and ceramic high-temperature electrical insulation parts. We thank Asheville Mica Energy Solutions for its participation in this study.

PSA tape liner removal variables

It’s crucial that PSA tape selection considers mica’s relatively delicate nature (see Appendix 2 for a general overview of PSA tape selection). A potential issue relates to the tape’s release liner—the layer of film that protects the adhesive and is removed at the point of assembly.

As explained earlier, removing this liner can provide enough shear force to damage the mica surface to which the tape is bonded. Essentially, if the liner’s release force (the force needed to remove the liner from the tape construction) is greater than the break strength of the mica, then damage to the mica may occur.

Understanding liner release force

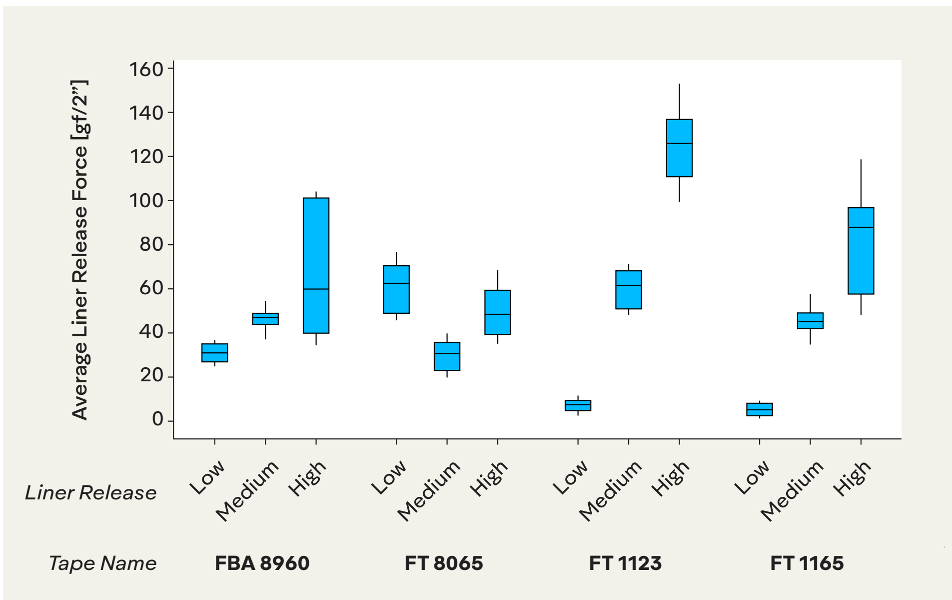
The first trial considered four tapes recommended for use in EV batteries (see Appendix 1 for an overview of tape constructions):

- **FBA 8960:** Double-coated tape with a general-purpose adhesive
- **FT 1123:** Transfer tape with a general-purpose adhesive
- **FT 1165:** Transfer tape with a flame-retardant adhesive
- **FT 8065:** Double-coated tape with a flame-retardant adhesive

These tapes' liners were further customized to require a low, medium, or high level of release force (a liner with a low release force is easier to remove than a liner with a high release force).

Multiple trials were performed involving bonding these tapes to a mica surface and removing the liners. The plots in Figure 1 show the forces required to achieve a "clean" release: one that does not damage the underlying mica.

Figure 1: Average Clean Release



Note, regardless of the liner's release force (low, medium, or high), the double-coated tapes achieved a clean release with less force than the transfer tapes. This is because a double coating of adhesive adds stability to the tape construction.

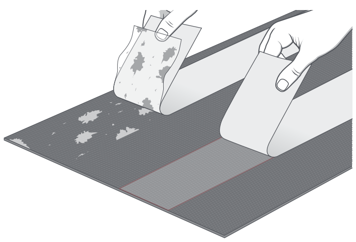
The general-purpose PSAs used in this trial are slightly tackier than the flame-retardant PSAs used, and they had slightly higher releases. In the most extreme case, the release force was only ~130 gf/2".

Understanding mica surface-break force

A second trial considered two types of mica that are used in EV batteries:

- **Muscovite:** A hydrated silicate of aluminum and potassium, muscovite tends to have higher electrical and chemical resistance and is the more rigid material.
- **Phlogopite:** Containing magnesium, phlogopite is generally used for higher temperature requirements. It is darker in color, softer, and more flexible.

During mica manufacture, a binder is added to these materials to form a sheet. For additional stability, these materials can be combined with a laminate such as glass scrim. Depending on the type and load of the binder, mica can be formed into flexible rolls or rigid parts that can be stamped and formed.



Removal of a PSA tape's liner can provide enough shear force to damage the mica surface.

The break force of the mica was measured using a standard ASTM D3330 test preparation method. Each mica laminate was treated as the substrate, and the unwind side of FBA 8960 was rolled onto a 2 mil PET backing with a standard . The backed FBA 8960 then had the liner removed, and rolled onto the mica surface with a 4.5 lb roller, and stored in a controlled humidity and temperature environment for 72 hours. The tape was then mounted to a high speed machine, where the mica surface was mounted with clamps and tape to a sled, and pulled apart at 300 in/min. The force required to pull the adhesive was recorded, and at the point of mica tear the peak force was recorded. This will be denoted as the "surface break force."

Each of the test materials was 0.5 mm thick.

The plots in Figure 2 show the surface break force for four types of mica.

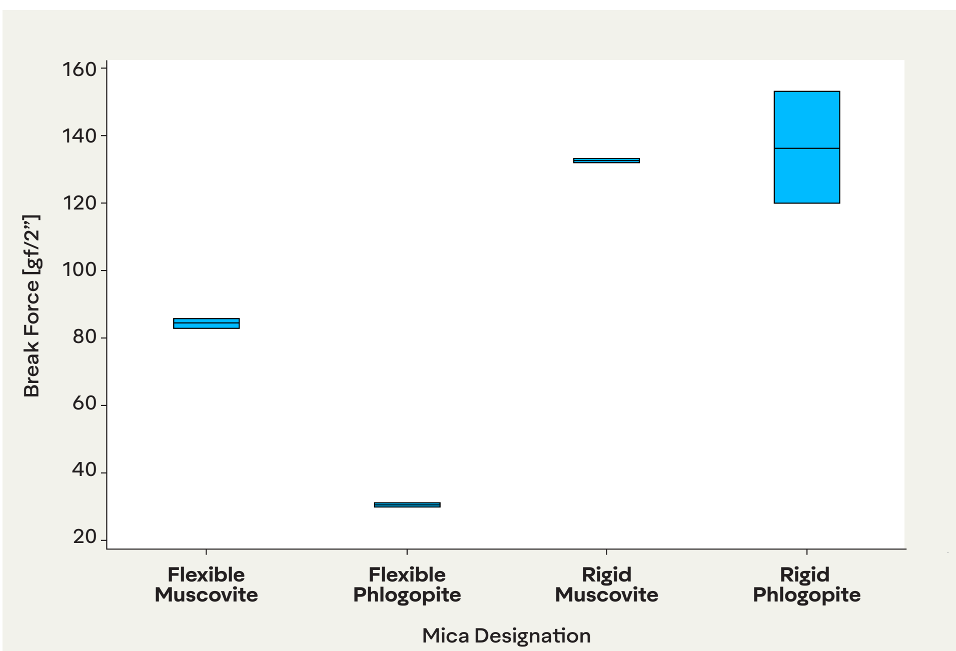
Note the peak surface break force for the rigid materials is much higher than for the flexible materials, while the surface break force for muscovite differs only when comparing the flexibles.

Liner confusion

If a liner's release force (see Figure 1) is greater than a mica's surface break force (see Figure 2), the liner will not be able to be removed without damaging the mica.

This phenomenon is referred to as "liner confusion." It may appear as if the adhesive has poor adhesion to the mica surface. But if the surface of the adhesive is covered in mica particles, the interlaminar forces of the mica are actually the "weak link" in the system.

Figure 2: Average Mica Break Force



Effect of adhesive pattern coating

Based on the results from Figures 1 and 2, one may conclude preventing mica damage is only possible by using double-coated tape (and even that will not work with flexible mica). However, an additional technique — known as adhesive pattern coating — can be used to prevent mica damage related to liner removal.

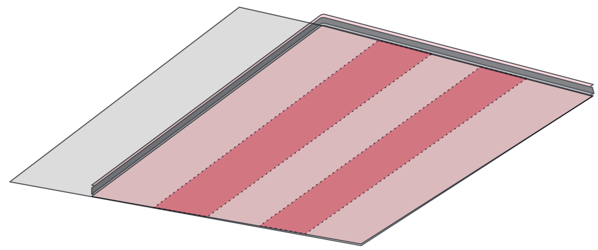
Adhesive pattern coating is an available option for double-coated tapes, which feature two layers of PSA on either side of a film carrier.

With adhesive pattern coating, the side of the tape that bonds to the mica features a full coating of PSA, while the side adhered to the release liner is only partially coated. This effectively lowers the force required to remove the liner.

Pattern coating for tapes used with mica

The next set of trials involved multiple samples of FBA 8960, a double-coated, general-purpose tape. One side of the tape featured a full coating of PSA. The other side was pattern coated, with the PSA applied in one-inch alternating stripes.

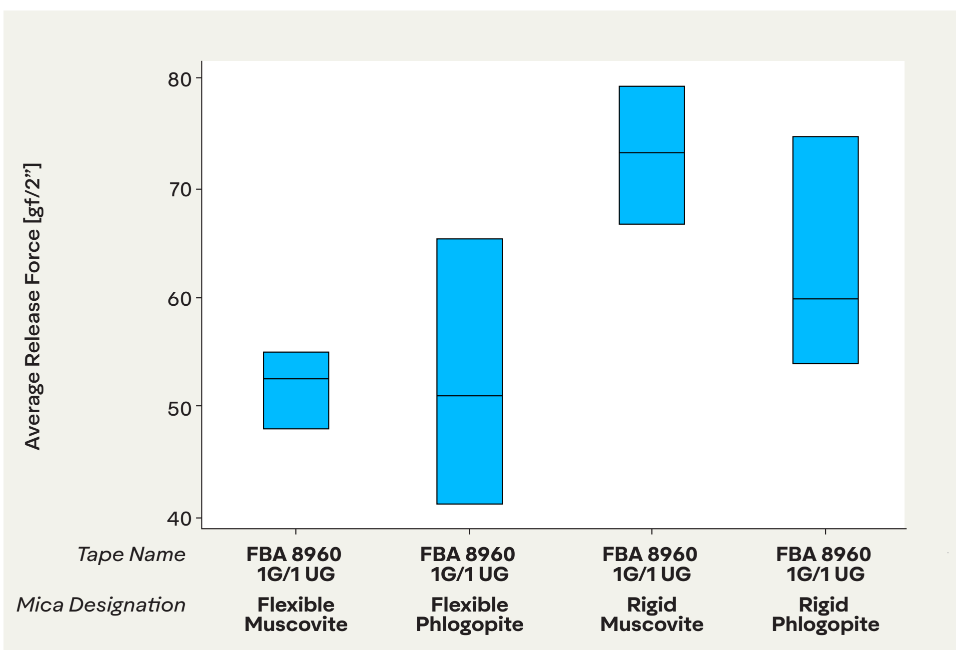
Multiple samples of this tape were bonded to various samples of mica, including rigid and flexible muscovite and phlogopite. In each case, the fully coated side was bonded to the mica, while the pattern-coated side held the release liner.



In a pattern-coated tape, the adhesive is laminated to its carrier in alternating stripes.

The release liners were then removed. The plots in Figure 3 show the average liner release forces.

Figure 3: Average Liner Release Force for FBA 8960



Results include rows where tape = "FBA 8960, 1G/1 UG"

In all cases, the liners were removed cleanly, without damaging the mica surface!

This result was only possible with the pattern-coating technique. Consider the case of flexible phlogopite, which, in Figure 2, showed a break strength near 20 gf/2".

It is important to note that double-coated tape stabilizes an underlying surface. Its use distributed stresses over a wider section of mica and essentially raised its break force.

Finally, understand while pattern coating is a powerful variable, it may not be appropriate for all applications. One must consider the size and weight of the parts versus the pattern, and the effectiveness of the adhesive when applied in a pattern.

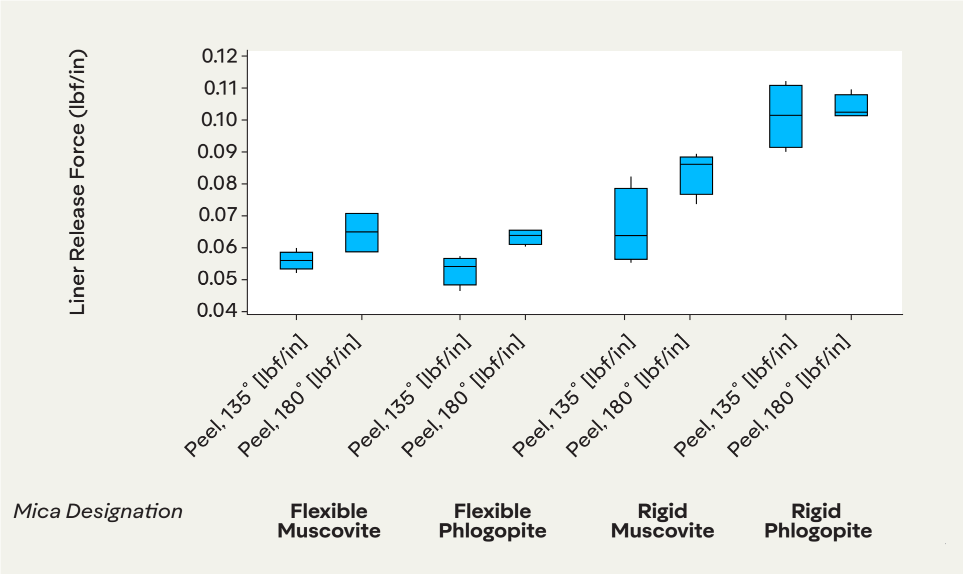
Effect of peel angle

Based on what is shown in Figure 3, it is clear distributed stress is a factor when evaluating adhesion.

But pattern coating is not the only way to create this distribution. Figure 4 shows the results when fully coated FBA 8960 tape was peeled at various angles from various mica surfaces. In this case, the peel force is displayed in pounds (rather than gf/2").

As FBA 8960 was peeled at larger angles, the distributed stress is more in the x-direction, and less in the z-direction. This is giving a slightly higher tear force.

Figure 4: Average Liner Release Force—Variable Angles

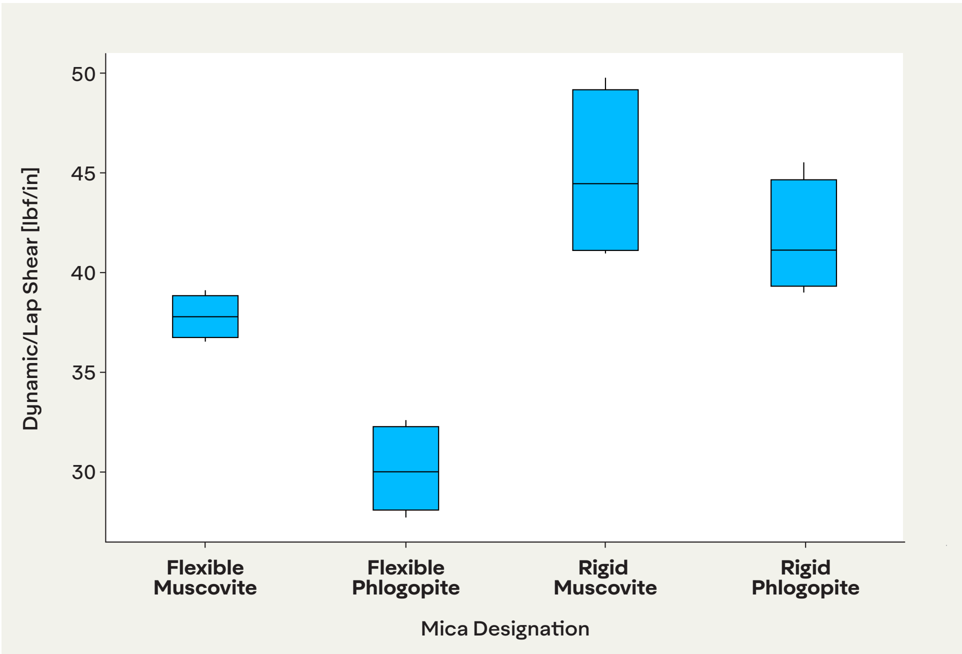


Once again, note rigid mica tears at higher force values than flexible mica, and rigid phlogopite tears at lower force values than rigid muscovite. However, all of these values are extremely low! Mica stressed in the z-direction tears at values << 1 lbf/in.

Compare this to dynamic shear (also called lap shear). Dynamic shear is where the adhesive acts as a bond between two layers of mica. These two layers are then forced apart in oppostie directions, which is forcing a parallel shear failure almost entirely in the z-direction. Figure 5 shows, lap shear of mica bonded with FBA 8960 produced values as high as 45 lbf/in. Why is this?

Mica is a platelet particle, and its surface tore easily in the z-direction. However, in the x/y-plane, the plates are effectively more densely packed. Liner release forces in this direction were up to 400 times higher!

Figure 5: Mica Dynamic Shear



Conclusion

The use of mica composites bonded with high-performance PSA tapes has emerged as an effective material solution to the challenge of thermal runaway protection in EV batteries.

However, OEMs and battery pack manufacturers specifying this solution should take care to prevent mica damage caused by the removal of the tape's liner during assembly. This means considering factors such as mica type, adhesive selection and tape construction, and possibly using techniques such as pattern coating or manipulation of liner release angle.

Avery Dennison Performance Tapes offers a wide range of consultative services, including application and engineering support. We welcome the opportunity to discuss your unique needs and ensure you specify the right tapes for your EV battery pack design. Learn more at tapes.averydennison.com/evbattery.

Asheville Mica Energy Solutions is one of the largest mica material and part manufacturers in the U.S. The company provides fast quotations, DFM and material selection consulting, and rapid prototyping. An ISO 9001 certified operation, Asheville Mica Energy Solutions offers muscovite, phlogopite and synthetic mica, along with components manufactured from ceramic, fiberglass, carbon fiber, Nomex®, Kapton®, aerogel, polymers, foams, and various laminated materials.

Appendices

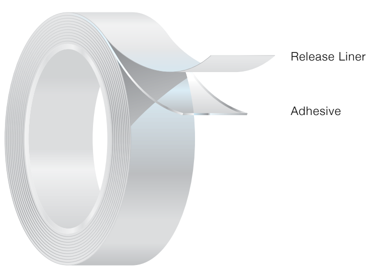
Appendix 1: PSA tape overview

High-performance PSA tapes are used in a wide variety of industries, including automotive, aerospace, building and construction, appliances, healthcare, print and packaging, electronics, and commercial transportation. As a bonding solution, tapes are valued for their versatility, durability, ease of use, and other advantages.

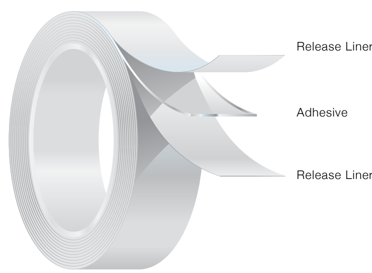
As a leading global tape manufacturer, Avery Dennison offers adhesive chemistries including conventional rubber, High Performance Acrylic (HPA™), and Acrylic Foam Bond (AFB™). Our portfolio contains hundreds of PSA formulations and filmic carriers. This enables a high degree of customization for an application's specific needs.

We offer tapes configured into multiple types of construction, again based on the needs of an application.

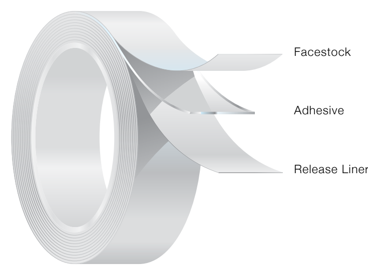
- **Single-liner transfer tape:** A single layer of adhesive sandwiched between two layers of silicone release liner.
- **Double-liner transfer tape:** A single layer of adhesive protected by a single layer of silicone release liner.
- **Single-coated:** Adhesive laminated to a single side of a film carrier. The exposed adhesive is protected by a silicone liner.
- **Double-coated:** Adhesive laminated to both sides of a film carrier. The exposed adhesive is protected by a silicone liner.
- **Double-coated, differential:** A double-coated construction featuring a different adhesive type on each side of the film carrier.



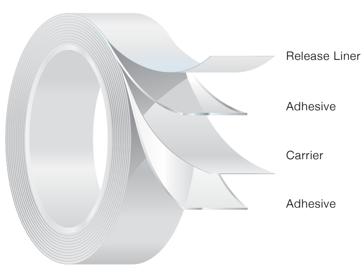
Single Liner Transfer Tape



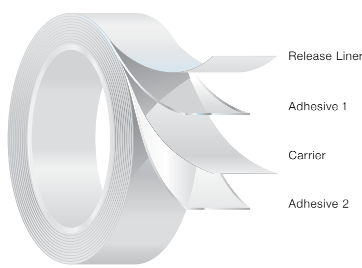
Double Liner Transfer Tape



Single Coated Tape



Double Coated Tape



Differential Tape

Appendix 2: PSA tape selection guidance for EV batteries

PSA tapes are available with a wide range of adhesive chemistries and in various configurations. It follows that there are multiple factors to consider when choosing a tape for bonding mica within an EV battery pack. Avery Dennison offers application support to help customers choose the optimal tape solution.

This overview is not intended as a substitute for that support, but to help the reader understand the thought process needed when selecting a tape.

Substrate features

- What is the surface energy of the substrate being bonded to within the pack? Is it a high-surface energy material such as polyurethane foam or aluminum? Or is it a low-surface energy material such as polyethylene plastic?
- What is the texture of the substrate? Is it a rough, irregular surface requiring more adhesive? Or is it smooth?
- What is the part tolerance, and what gap fill will the PSA need to hold?
  - Part gaps may need to be thin (<50 μm) to maximize space.
  - If warping is expected, or wider part tolerance gaps (0.3 - 2 mm) are needed, a foam tape may be required.

Operating / environmental conditions

- What service temperature range will the tape be exposed to?
- What temperature range will the tape be exposed to during application?
- Does the tape need to hold a part around a contour under stress?
- How flame retardant will the tape need to be? Is it expected to bear the brunt of thermal runaway, or will mica or other materials partially protect it?
- Will thermal and/or electrical conductivity need to be considered? Should the tape help prevent electrical arcing, or pull heat away from parts with higher thermal conductivity?
- Will the tape need to wrap or bend around a rigid part?
  A mica laminate may want to return to its original shape. This continuous stress is different than impact stress and requires a different type of tape.

Assembly considerations

- What is the application speed, and how fast will the tape be applied? Speeds can range from one to two parts per minute with manual application to more than 10 parts per second with automated systems.
- Will the tape be die-cut to a specific geometry?
  A double-coated tape would be recommended for easier cutting.
- Will the tape be configured into spooled rolls?
  A double-linered tape would be required.

Contact Avery Dennison to learn more

If you are an OEM, automotive tier supplier or converter looking to better understand the potential for PSA tapes in EV batteries, please contact me directly at luke.johnson@averydennison.com.

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

Connect with us on:

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