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THERMALLY REMOVABLE OPTICAL ADHESIVE LAMINATES

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Introduction and Background

This paper will present the concept, data and examples pertaining to the use of thermally shrinkable films in an adhesive construction as a mechanism to debond rigid or semi-rigid optical substrates.

While much effort has been expended in the development of adhesives that provide stronger adhesive bonds, bonds to a wider range of substrates, and that have a variety of additional properties such as weatherability, optical clarity, etc…, less effort has been spent on the development of de-bondable adhesives. If at least one of the substrates that are bonded is a flexible substrate then these substrates can often be debonded by peeling the flexible substrate from the rigid substrate. However, with rigid or semi-rigid substrates, this removal by peel mechanisms is thwarted. This difficulty results regardless of the strength of the adhesive layers, since the overall article resists peeling. An example of this effect has been observed by any student who has placed a drop of water between two microscope slides. Attempts to peel apart the two slides, even though they are primarily held together by the surface tension of water, are generally difficult and the slides have to be slid apart, which is a shear force, and only useful if the bond material is extremely weak cohesively.

The desire to bond and debond optical components has been driven by the display and electronics industry and the popularity of mobile hand held devices in particular. Bonding of touch sensors to LCD modules, front lights on e-readers and the processing of ultra-thin glass are examples of rigid and semi-rigid substrates that can be optically bonded and therefore sometimes it is necessary to debond. Debonding enables recovery of expensive optical components in manufacturing; removal and replacement of damaged components and separation of components at the end of life of a device.

Therefore, adhesive articles that are heat debondable are desirable. The term "heat debondable" refers to adhesive articles that upon the application of heat undergo a change in the adhesive bond such that one or both of the substrates can be removed from the adhesive layer. A heat debondable, adhesive construction permits the adhesive layer to have a useful lifespan holding together the substrates and also permits the removal of the substrates any time thereafter.

An added advantage of heat debondable articles is that by using a heat shrinkable substrate to induce the debonding, heating causes a permanent change in the article. In other words, once the article has been heated and the heat shrinkable substrate has shrunk, the article does not go back to its pre-heated state upon cooling. This permits the article to be heated, cooled and dismantled. The article does not have to be dismantled hot. This is in contrast to, for example, systems where the adhesive layers are thermally sensitive and lose their adhesive strength upon heating, but regain their adhesive strength upon cooling.

Adhesive articles in this report are referred to as optically clear. Optically clear is defined as high light transmittance over a majority of the visible light spectrum (about 400 to about 700 nm), and low haze. Optically clear adhesives and articles generally have greater than 90% transmittance and haze values less than 5%.

Adhesive articles are described that are multi-layer constructions that comprise a heat shrinkable film with an optically clear adhesive disposed on each surface. Figure 1 illustrates this basic concept, laminated between two rigid or semi-rigid substrates. The optically clear adhesives may be the same or different. The adhesive articles may be considered transfer tapes with an intervening layer that is a heat shrinkable film. The heat shrinkable film has a threshold Shrink Force (described below) and the adhesive layers have a Failure Force (described below) such that the adhesive article forms heat debondable adhesive bonds when adhered to rigid substrates.

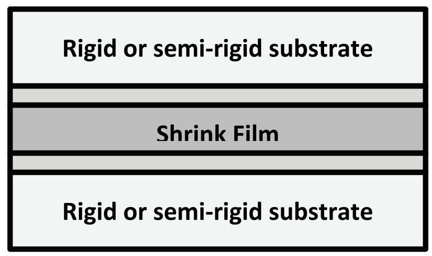

Figure 1. Heat debondable, adhesive construction laminated between rigid or semi-rigid Substrates

Heat-Shrinkable Substrates and Shrink Force

Heat shrinkable films are substrates that are responsive to the application of heat, and may be considered a subset of the broader class of shape memory polymers. Typically, the heat shrinkable film has been heated, stretched and cooled under tension. The stressed or stretched film, upon the application of heat, relaxes toward the pre-stressed state to release the energy stored in the polymer. It is this release of energy that provides the shrink force for the substrate. Additionally, as the heat shrinkable film shrinks in length and or width, it grows in thickness to maintain a constant volume. This growth in thickness provides an additional impetus for separation of the bonded substrates, namely the growth in thickness provides a piston like action that helps to force apart the rigid optical substrates.

The shrink force is defined here as the maximum force per unit width developed by a film during a temperature ramp through the film's relaxation temperature range while the film is under restraint. The measurement is performed on the film in both orientations, machine and transverse, and the greater of the two values is designated as the maximum shrink force. Suitable heat shrinkable films have a threshold shrink force of at least about 100 grams per inch.

The shrink force of the heat shrinkable substrate, together with the appropriate choice of adhesives with a desired Failure Force, provides heat debondable adhesive bonds. Therefore, in general, it is the combination of forces, Shrink Force and Failure Force, cooperating that provides the heat debonding of rigid or semi-rigid substrates.

Product examples of clear heat shrinkable films are the so-called "shrink films" or "shrink wraps". Examples of suitable polymer films which can be used as shrink films are polyolefins, polyesters (PET) and polymethylmethacrylates (PMMA or commonly called acrylic film). The optically clear heat shrinkable film may be a single layer or a multi-layer substrate.

The films used to make examples and generate the data in this report are generally described in Table 1. The test method used to determine shrink force can be found in Appendix A.

Table 1. Shrink Films and Properties

Film Type	Thickness (microns)	Maximum Shrink Force (g/in)
Polyolefin	~ 50	430.4
Acrylic	~ 75	138.5
Polyester	~ 20	250.6

Figure 2 is a plot of Percent Linear Shrinkage vs Temperature for two of the films. Based on the polymer properties and heating conditions, the shrinkage vs temperature curves can be quite different and very useful data. The polyolefin based film begins shrinking at approximately 65C vs the acrylic film which is dimensionally stable to about 85C. Even though the maximum percent linear shrinkage is comparable, the maximum Shrink Force is quite different.

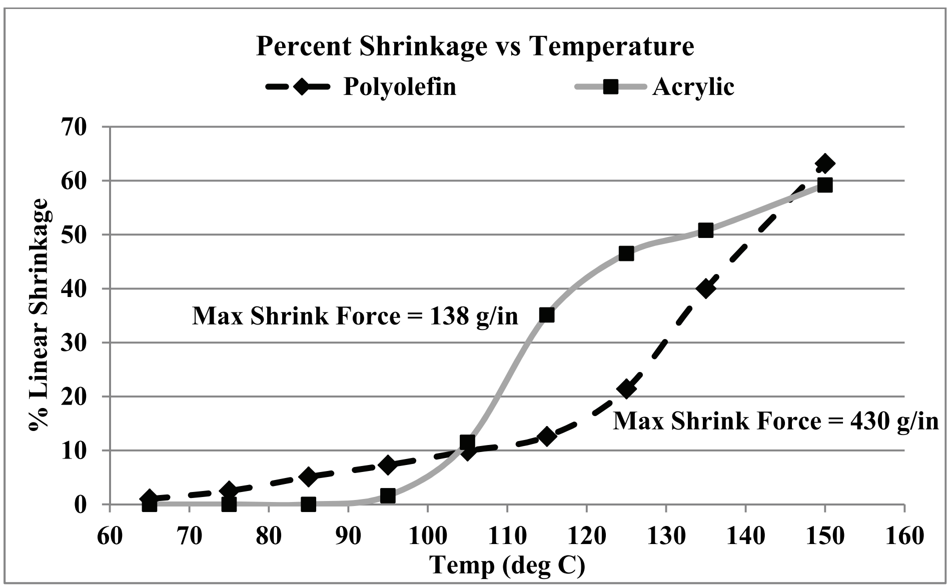

Figure 2. Percent Linear Shrinkage vs Temperature

Heat-shrinkable substrates can be multi-layer. A multi-layer substrate may be comprised of a central core of a heat shrinkable film with outer layers of a different film that is not heat shrinkable. The multiple layers may be adhesively bonded together or they may be laminated together through the use of pressure and/or heat. Some multi-layer substrates are prepared in a single step by multi-layer extrusion. The outer layers can become sacrificial layers upon the application of heat, meaning that they adhere more strongly to the adhesive layer than to the central heat shrinkable layer. Upon the application of heat the central heat shrinkable layer shrinks causing the bonds between the central heat shrinkable layer and the outer layers to fail. The heat shrink films described above can be used as the central heat shrinkable layer of the multi-layer substrate. The outer layers can be formed from any suitable optically clear polymeric film layer.

Adhesives, Failure Force and Heat Debond

A wide variety of optically clear adhesives can be used in these adhesive articles. Among the suitable classes of adhesives are heat activated adhesives, pressure sensitive adhesives, gel adhesives, curable adhesives, and hot melt adhesives. The choice of adhesive for the adhesive article depends upon a wide range of factors such as; the desired use for the adhesive article, composition of the rigid substrates to which the adhesive is to be bonded, the environmental conditions to which the adhesive article is to be exposed and the other components in the adhesive article, especially the heat shrinkable film.

Each adhesive layer in the construction exhibits a Failure Force. This Failure Force is dependent upon the composition and properties of the adhesive, interaction with the substrates to be bonded, as well interaction with the heat shrinkable substrate material, including if the heat shrinkable article is a multi-layer film or has an adhesion promoting or adhesion reducing coating.

The Failure Force is not measured directly for the adhesive article, but was modeled by the use of either 90° Peel Adhesion (12 ipm) at RT (room temperature) or 180° Peel Adhesion (12 ipm) at 100°C using a modified version of the Test Method ASTM D3330-90 (See Appendix A) to a glass substrate of a test sample comprising the adhesive layer disposed on the heat shrinkable substrate. In other words, a test "tape" is prepared with the adhesive layer using the heat shrinkable substrate as the backing. A conventional Peel Adhesion test is then run using a glass substrate to measure the Failure Force value as in Figure 3. The use of an elevated temperature test allows adhesives to be characterized that may not be evaluated at RT, but do have measurable Failure Force under conditions more closely approximating the use conditions for the actual article when being heated. An example of such an adhesive is a hot melt adhesive. These adhesives can be cohesively quite strong at RT, but upon heating the cohesive strength drops dramatically, permitting cohesive failure.

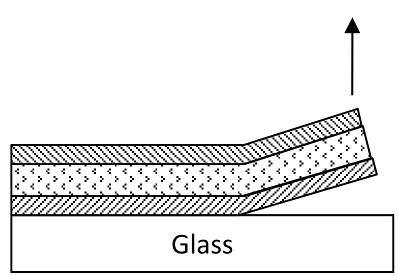

Figure 3. Initiating Peel for 90 deg Peel test; Determination of Adhesion Failure Force

Just as the Shrink Force is a characteristic and measurable physical property of the heat shrinkable film, the Failure Force is a characteristic and measurable physical property of the adhesive and its interactions. It should be noted that the Failure Force is a value associated with the adhesive and its interactions, and is measured by the Peel Adhesion tests described above, but does not refer to failure or debonding of the overall adhesive construction. While it has been found that articles that have the desired combination of threshold Shrink Force and Failure Force will debond upon heating as desired, the Failure Force Peel Adhesion test is simply a model test used to characterize the adhesive and the interfacial forces in each construction type

The Failure Force is used as a model test because testing of the actual laminated adhesive articles is either very difficult or impossible. Because many of the articles contain substrates that are rigid or semi-rigid, conventional peel adhesion tests cannot be run on these articles directly. Therefore, the Failure Force, in conjunction with the threshold Shrink Force, is used to determine which adhesives and heat shrinkable films yield suitable combinations.

Determination of Failure Force Peel Adhesion values is a useful screening method, since they are correlated to observed failures in adhesive articles, as will be shown by the examples. It must be noted however that the Failure Force values are only one factor for determining whether the adhesive article will debond upon heating. Other factors to take into account include the threshold shrink force of the heat shrinkable substrate, the failure mode (discussed on following pages), heating method and conditions and the mass of the adhesive article. The Failure Force applies to both the first and second adhesive layer. If the adhesive layers are the same, only one test need be run, but if the adhesive layers are different, the Failure Force for both adhesive layers must be determined.

It must be reiterated that Failure Force values were attained when the adhesive article was laminated to one piece of glass. Then either 90 deg peels at RT or 180 deg peels at 100ºC were obtained. Then adhesive articles with the same combination of materials were laminated between two pieces of glass and tested to determine whether this specific construction would debond the glass slides upon heating. The Shrink-Off Debond Test method can be found in Appendix A.

Generally the method of debonding comprises application of heat to the adhesive article laminated between two optical substrates to induce shrinkage in the heat shrinkable substrate. This shrinkage generates the shrinkage force that drives the adhesive failure. The adhesive must fail at two interfaces within the multi-layer construction to allow the shrink film to fully shrink. Generally the heat applied is sufficient to generate the threshold shrink force but is not sufficient to degrade or damage other components of the article. The temperature and time at that temperature which are able to generate the threshold shrink force vary with different films. Typically the laminates are heated to 100 to 150°C for a time of from 1 to 15 minutes. However, temperatures and heating times can vary based on the mass of the substrates involved, as well as many other factors.

Debonding may be carried out immediately after an optical laminate is formed if defects are detected. A wide range of defects are possible and the ability to debond the article and remake the article can provide major cost and time savings. For example, if one of the optical substrates is the surface of an optical device and the defect is the entrapment of dust or some other contaminant that renders the optical device unusable, a quick debonding process and re-bonding to form a new device can prevent expensive components from being scrapped because of the defect. The debonding may also occur at a time far distant from the assembly of the laminate, for example at the end of service life of the article.

Failure Mode Scenarios

For a heat shrinkable adhesive construction to be able to debond two rigid or semi-rigid substrates, the shrink force of the film must overcome the failure force of the adhesive bonds. The adhesive bonds must fail at two interfaces, within the multi-layer construction, to allow the shrink film to fully shrink. Dependent on the materials in the heat shrinkable adhesive construction, there are basic Failure Mode Scenarios, which describe where the interfacial failure is occurring to allow film shrinkage and debonding.

Basic Failure Mode Scenarios:
- Adhesive Failure from the glass substrates
- Adhesive Failure from the heat shrinkable film
- Cohesive Failure of the adhesives
- When the film core is a multi-layer film, Inter-layer Failure between film layers

These are only basic failure modes, which assume a symmetrical construction, combinations and variations of these failure modes are possible and probable, dependent on material selection and overall construction design.

Other scenarios are possible if one of the substrates is a non-rigid substrate or if the heat-shrinkable article is only used in the perimeter of the laminate as a rim tape.

Other Concept Scenarios using Heat Shrinkable Laminates:
- Flexible to Semi-rigid Substrates, where semi-rigid substrate is too fragile to allow a peel force
- Rim Tape using a heat shrinkable film or construction

These scenarios are described below, accompanied by examples. All of the combinations of materials and constructions used in the following examples were optically clear, as defined by greater than 90% transmission and less than 5% haze, unless noted otherwise.

Basic Failure Mode Scenarios

Adhesive failure from the glass substrate

Assuming that both adhesive layers are the same, this means that the Failure Force of both adhesive layers is the peel force from the glass substrate. This failure mode is the failure mode typically observed in peel tests for pressure sensitive adhesives. In this failure mode, no adhesive (or essentially no adhesive) is left on the glass substrate; the adhesive remains on the heat shrinkable film. See the schematic in Figure 4 and accompanying examples in Table 2.

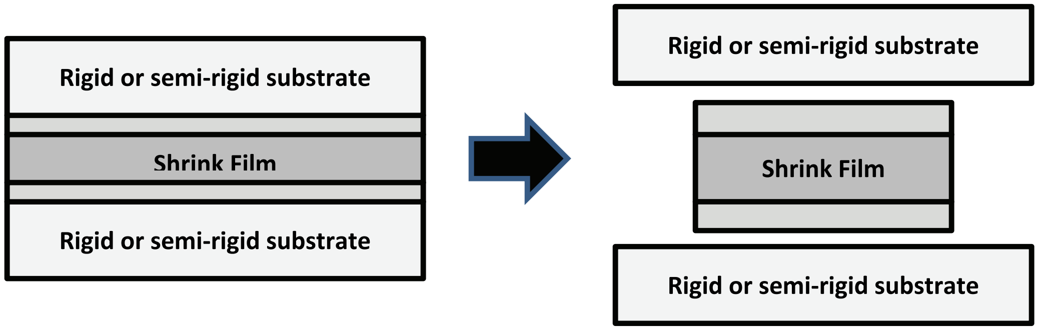

Figure 4. Adhesive failure from the glass substrates

For the polyolefin film used in these examples, it was necessary to coat a primer before coating or laminating the adhesives. This enabled sufficient bond to the polyolefin film, providing higher bond to the film than the glass substrate.

Peel adhesions that allow debonding to occur in the examples in Table 2 are less than 100 g/in. The polyolefin film, with the highest shrink force, was able to overcome a slightly higher adhesion/failure force when compared to the other film types.

Table 2. Examples for Adhesive failure from glass

PSA	Peel adhesion from Glass @ RT (g/in)	Film Type	Separated glass slides upon heating
PSA 1	29.2	Polyolefin w/ primer	Yes
PSA 2	44.1	Polyolefin w/ primer	Yes
PSA 3	83.5	Polyolefin w/ primer	Yes
PSA 4	99.6	Polyolefin w/ primer	No
PSA 5	232.2	Polyolefin w/ primer	No
PSA 1	29.2	Acrylic	Yes
PSA 2	44.1	Acrylic	Yes
PSA 3	83.5	Acrylic	No
PSA 4	99.6	Acrylic	No
PSA 5	232.2	Acrylic	No
PSA 1	29.2	Polyester	Yes
PSA 2	44.1	Polyester	Yes
PSA 3	83.5	Polyester	No
PSA 4	99.6	Polyester	No
PSA 5	232.2	Polyester	No

Adhesive failure from heat shrinkable film
In this failure mode scenario, the heat shrinkable film is peeled away from the adhesive layer, leaving the adhesive layer on the glass substrate. This scenario is different from the first failure mode scenario described above in that in this failure mode the heat shrinkable substrate debonds from the adhesive layers. Refer to Figure 5 to illustrate this failure mode and Table 3 for examples.

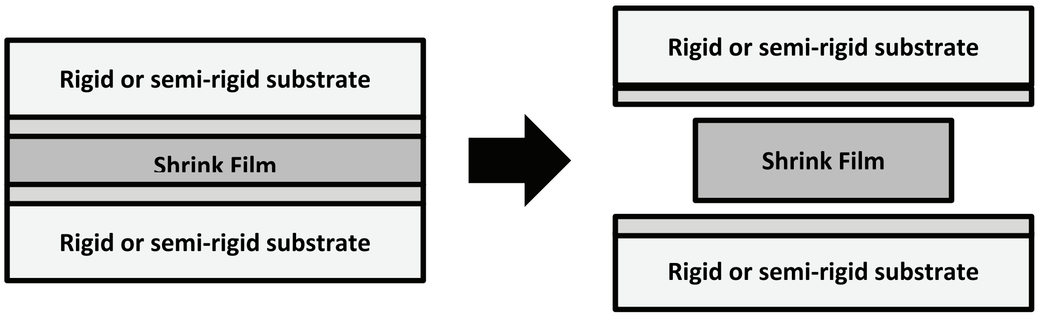

Figure 5. Adhesive failure from the heat shrinkable film

The polyolefin film used in these examples was used without primer. The lower surface energy of the polyolefin film provided lower adhesive bond to the film than the glass substrate. Conversely, the acrylic film in these examples has a release coating applied to the film, which provides lower adhesive bond to the acrylic film than the glass substrate.

Table 3. Examples for Adhesive failure from heat shrinkable film

PSA	Peel adhesion from Film @ RT (g/in)	Film Type	Separated glass slides upon heating
PSA 6	31.3	Polyolefin w/o primer	Yes
PSA 7	79.4	Polyolefin w/o primer	No
PSA 8	96.6	Polyolefin w/o primer	No
PSA 6	25.2	Acrylic w/ release coating	Yes
PSA 7	32.5	Acrylic w/ release coating	Yes
PSA 8	67.4	Acrylic w/ release coating	No

Cohesive failure of the adhesive(s)
In this failure mode, when a Peel Adhesion Test is run using a glass substrate, the adhesive cohesively splits and some adhesive is left on the glass substrate and some adhesive is left on the heat shrinkable substrate. For the debonding to occur in this scenario, both adhesives must cohesively fail. This failure mode is shown in Figure 6 with examples in Table 4.

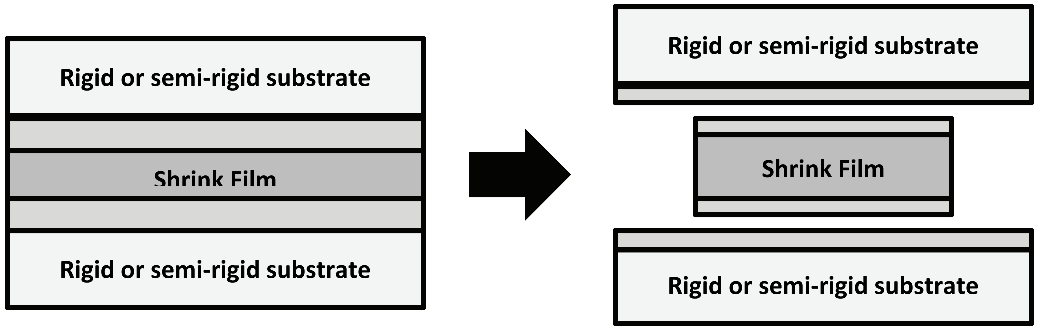

Figure 6. Cohesive failure of the adhesive(s)

Many materials may be high bond and cohesively strong at lower temps, but cohesively weak at higher temps; for example, hot melt adhesives. Therefore the peel adhesion values for Failure Force for this scenario were measured at 100°C to account for such materials. The test method used to determine the peel values at elevated temperature can be found in Appendix A.

Table 4. Examples for Cohesive failure of adhesive(s)

PSA	Cohesive Peel Force @100C (g/in)	Film Type	Separated glass slides upon heating
PSA 9	0.91	Acrylic	Yes
PSA 10	1.72	Acrylic	Yes
PSA 11	7.2	Acrylic	No

Multi-layer heat shrinkable film, Inter-layer failure between film layers
In this failure mode scenario, the Failure Force is a measure of the inter-layer force between the layers of the multi-layer film core. The failure occurs between layers of the multi-layer film core, and the adhesive remains adhered to the glass substrate together with at least one layer of film, as illustrated in Figure 7, and by the example in Table 5.

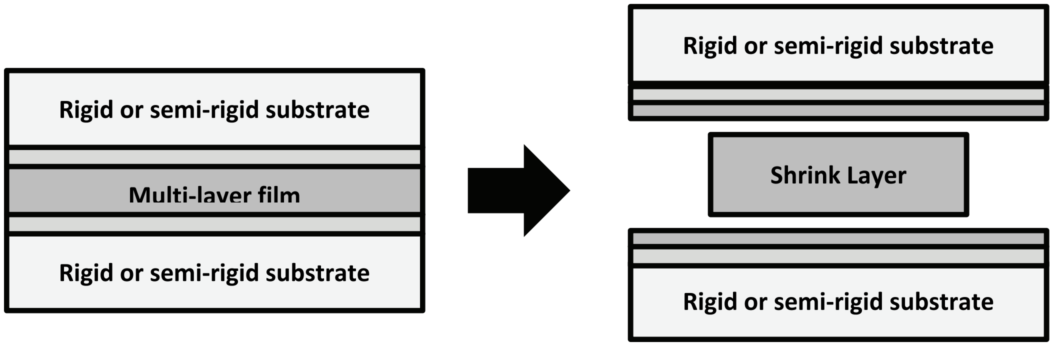

Figure 7. Inter-layer failure in multi-layer film core

Table 5. Example for Inter-layer failure in multilayer film core

PSA	Interlayer Delamination Peel Force @RT (g/in)	Film Construction	Separated glass slides upon heating
PSA 7	11.3	Polyurethane film heated laminated to each side of Acrylic film	Yes

As described above, each of these basic failure mode scenarios is a model of the adhesive article when bonded between two rigid substrates. The model is useful to describe the adhesive article because the failure modes of the model mimic the failure modes of the adhesive article when heated to cause debonding. When the adhesive articles are heated, the shrink force of the optically clear heat shrinkable film provides a force to cause the desired debonding. Additionally, the debonding of the actual adhesive articles may be a combination of these failure mode scenarios.

Other Heat Debond Scenarios

Flexible-to-Rigid Substrates

When the articles comprise a heat shrinkable optical film, an optically clear adhesive and a rigid optical substrate, in other words flexible films bonded to rigid substrates, other failure modes are possible. In these articles, because the heat shrinkable optical substrate is not bonded to a second rigid substrate, the heat shrinkable optical film may curl upon shrinkage. When the heat shrinkable film curls upon itself it may carry with it the adhesive layer or a portion of the adhesive layer or it may be free of the adhesive layer. In other words, the adhesive layer may fail adhesively from the rigid optical substrate, the adhesive may fail cohesively, the adhesive may fail adhesively from the heat shrinkable optical film, or the adhesive may fail by a combination of these modes.

In most cases, the flexible substrate and PSA could simply be peeled from the rigid substrate. However in the special case of a fragile rigid or semi-rigid substrate, such as thin flexible glass substrates, the force of the peeling action may damage or break the fragile substrate. In this case, it would be advantageous to heat debond the flexible substrate. See Figure 8 and examples in Table 6.

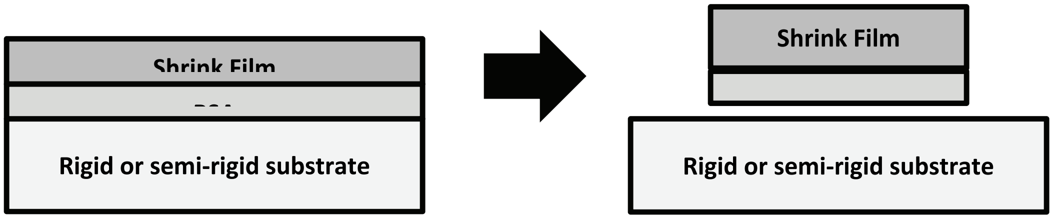

Figure 8. Heat debonding flexible from rigid or semi-rigid substrate

Table 6. Examples for Heat Debonding Flexible Substrates from Rigid Substrates

PSA	Peel Force from Glass @RT (g/in)	Film Type	Shrink Film and PSA curls from glass upon heating
PSA 3	83.5	Acrylic	Yes
PSA 5	232.3	Acrylic	Yes
PSA 12	396.0	Acrylic	Yes
PSA 7	1212	Acrylic	No

Heat Shrinkable Construction as a Rim Tape

Rim Tapes consisting of heat shrinkable constructions, while being present over only a small portion of a laminate, can provide heat debonding. These laminate constructions utilize the combination of a heat shrinkable film or construction and a proximate adhesive layer (adhesive in the bulk of the laminate area, which is typically the optical portion of the laminate) with the desired properties to achieve heat debondable articles. Additionally, there may be one or more adhesive layers present on the heat shrinkable rim tape to adhere it to the other components in the construction. As per the previous examples, the shrink force of the heat shrinkable film provides the heat debonding force for the laminate, but in this case, the rim tape may also act as a wedge. This concept is shown in Figure 9.

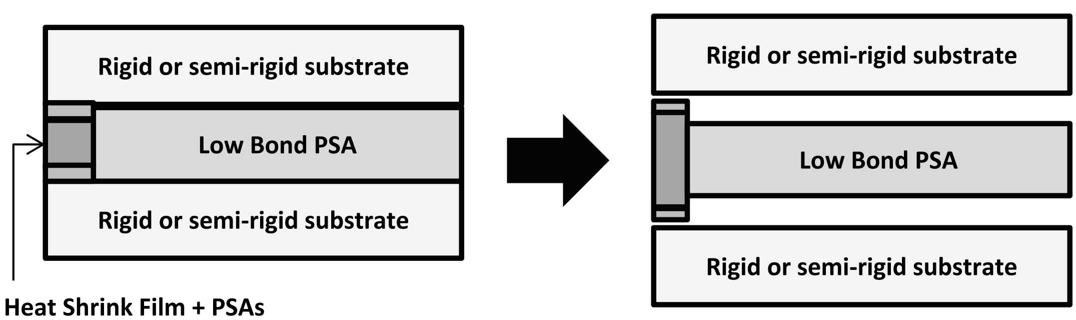

Figure 9. Heat shrinkable construction as a Rim Tape

For these laminates it is not necessary that the rim tape be optically clear, as rim tapes in display constructions typically reside outside the viewing area. The rim tape may have adhesive layers on each side of the heat shrink film, may have adhesive only on one side of the film or no adhesive on the film. In the case of no adhesive on the shrink film, the proximate optical adhesive can hold the shrink film in position in the laminate. The examples in Table 7 all include a low bond PSA on both sides of the shrink film. The rim tape can reside on only 1 side or up 4 sides of the laminate.

Table 7. Examples for Heat shrinkable constructions as Rim Tape

Rim Tape Description	Number of edges of Rim Tape	PSA Type and Thickness in the body of Laminate	Separated glass slides upon heating
Polyolefin film, 25 microns of PSA 2 on each side	1	PSA 2 ~ 100 microns	Yes
Polyolefin film, 25 microns of PSA 2 on each side	2	PSA 2 ~ 100 microns	Yes
Polyolefin film, 25 microns of PSA 2 on each side	4	PSA 2 ~ 100 microns	Yes
Polyolefin film w/ primer, 25 microns of PSA 2 on each side	1	PSA 5 ~ 100 microns	No
Polyolefin film w/ primer, 25 microns of PSA 2 on each side	2	PSA 5 ~ 100 microns	No
Polyolefin film w/ primer, 25 microns of PSA 2 on each side	4	PSA 5 ~ 100 microns	Yes
Acrylic film, 25 microns of PSA 2 each side	1	PSA 2 ~ 125 microns	Yes
Acrylic film, 25 microns of PSA 2 each side	2	PSA 2 ~ 125 microns	Yes
Acrylic film, 25 microns of PSA 2 each side	4	PSA 2 ~ 125 microns	Yes

Use of heat shrinkable rim tape on a single edge of a laminate can debond a low bond PSA when present in the body of the laminate. Use of a heat shrinkable rim tape on the entire perimeter (all four sides) of a laminate was able to debond a PSA in the body of the laminate with a higher failure force, than a full heat shrink construction.

Conclusions

The examples show that a variety of materials and constructions can be made that will result in optical heat debondable constructions.

As observed in the majority of the rigid-to rigid data, the maximum failure force or peel adhesion was less than 100 g/in, to allow the shrink films used in these examples to shrink and debond two rigid substrates. This is a viable concept for applications where low bond adhesion is acceptable to bond two rigid substrates. Flexible debondable articles were identified for use in the special case of fragile semi-rigid substrates. Rim tape constructions were identified that allowed debonding of rigid-to-rigid substrates at higher adhesion values than a full laminate heat debondable article.

Literature Citations

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2. Rule, J., Lewandowski, K, and Determan, M. (2009), “Debondable Adhesive Article”, Patent Application Publication WO2013012973

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Appendix A. Test Methods

Shrink Force Test Method

Shrink force tests were conducted by adapting the method in ASTM D2838-90 (1980), Procedure A, to be done using the appropriate equipment with film tension grips in strain mode. Test specimens with a width of 6.3 mm (0.25 in) were cut from a larger piece of shrink film in an orientation parallel to either the machine direction or the transverse direction. The strips were mounted in the grips with an initial grip separation between 24 mm and 25 mm. Below 30°C, the sample was stretched slightly to a strain level between 0.005% and 0.05%, and that length was maintained as the temperature was increased at a rate of 3°C/min. The force required to maintain the constant length was recorded until the shrink force had passed through a maximum. Tests were conducted with samples from both the machine direction and the transverse direction, and the maximum force observed in those two tests was divided by the width of the test sample to calculate the shrink force. The temperature at which the maximum shrink force was observed was also reported.

180 degree High Temp (100°C) Peel Adhesion Test Method

This peel adhesion test is similar to the test method described in ASTM D 3330-90, substituting a glass substrate (15.2 cm x 2.7 cm x 0.3 cm) for the stainless steel substrate described in the standard. Adhesive coatings on film were cut into strips 25.4 centimeters wide and between 15 cm 20 cm long. Each strip was then adhered to a clean, solvent washed glass coupon using a 2-kilogram roller passed twice over the strip. The bonded assembly dwelled at room temperature for at least 18 hours. One end of the adhesive-coated film was peeled off the glass a distance of 2.5 cm, and each face of this tab was attached to pieces of polyester tape, 2.5 cm wide and 20 cm long. The 2.5 cm section of uncovered glass substrate was loaded into the bottom grip of a load frame (within an environmental chamber at 100°C. The polyester tape was placed in the top grip of the load frame. The sample was left in the environmental chamber for three minutes to equilibrate, and was then tested for 180° Peel Adhesion at a rate of 30.5 cm/minute for a total peel distance of at least 12 cm. The peel value was calculated by averaging the loads that were observed over the peel distances between 2.5 cm and 7.5 cm. Three samples were tested for each adhesive, and the average peel value for the three was reported.

Debond Test Method

Glass laminates were prepared using two 50mm x 70mm x 1 mm glass slides. The adhesive article was laminated to the first glass slide and then the second glass slide was subsequently laminated. If the wet out area of the laminate was less than 80%, the sample was redone or autoclaved (60C @ 60 psi for 30 min) to achieve. A thermocouple end was attached to the backside of the bottom glass slide of a glass slide sandwich with high temperature tape. The glass slide sandwich was placed on a metal rack to rise off the bench top. Using a conventional heat gun, heat was applied by slowly moving over the surface of the top glass slide. Heat was applied to the sample until the film in the PSA/Film construction had visibly shrunk enough to separate the two glass sides. The temperature of the backside glass surface was recorded. The construction was cooled sufficiently to handle by hand, and if the glass slides separated, then the sample was designated as "Yes". Glass slides must be able to be separated with finger pull only, no prying or wedging with an implement. If sufficient film shrinkage had not occurred to initiate separation of glass slides, and backside glass temperature reached 150°C, the test was terminated. If glass slides could not be separated by fingers alone or backside glass temp exceeded 150°C without significant film shrinkage, the sample was designated as "No”.