

Hot Melts Hold Fast Until Ready with UV-Cured Release Liners

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The quality of pressure-sensitive adhesive (PSA) labels and tape is often judged long after products are wound and packaged. These products can be subject to wide swings in temperature, and not called into action until months later. Yet when the time comes, the adhesive must release cleanly from the liner, without tears or undue tack. Adhering too strongly (or releasing too early) can frustrate customers, and in high-speed food and beverage labeling operations, delays can be costly.

A PSA "laminate" is composed of two main layers, the label (or tape) facestock and the liner, with a PSA and silicone release-coating laminated between (see illustration). The silicone coating and liner material make up the release liner. Understanding the variables involved in PSA label construction and performance can help optimize labeling operations and cut costs.

Some printers and converters simply buy ready-to-print label rollstock (with all four components). Many, especially those familiar with "release" issues, want to create their own rollstock for greater control and higher speeds. They may buy a pre-coated siliconized liner, then apply a PSA, and laminate the liner and label together. They may even formulate their own adhesive, which can be applied to either the label or release liner side. With clear facestock, the label can be reverse printed so there's no need for a protective coating.) Or they may use in-line equipment that can siliconize the liner, apply adhesive, and print the label all in one high-speed process (see photo).

With radiation-curable (RC) silicones as the liner release coating, energy savings can be significant compared to thermal-cure coating systems. And with in-line coating of silicone and adhesive, cost savings can range 30 percent or more. Equipment for coating and UV curing these silicones can be extremely compact, making retrofitting into existing adhesive coating lines easy. In-line coating equipment is available both for truly high-speed wide-web and narrow-web printing lines.

Hot melt adhesives are widely used to produce PSA labels and tapes on a variety of paper and plastic liner materials. Because hot melts are designed to take the heat, shipping and storage temperatures are unlikely to present a problem for the adhesive (when properly stabilized with antioxidants). What can present an issue, however, occurs between adhesive and liner material. The cold-cure UV-silicone liner coating must provide a barrier between the liner material and adhesive without undergoing undue interactions that can affect proper release. One key measure of that performance is the opening force, and it should remain constant for a long period.

Adhesive testing

Accelerated aging can be simulated in laboratory testing by increasing temperature and pressure. Such a test can take six months of storage time, so testing every new laminate on an ad hoc basis can be cumbersome. A well designed study involving multiple formulations can provide a panoramic view and yield greater insight into materials and the curing process.

In a recent systematic evaluation, the long-term aging performance of nine different formulations of hot melt adhesives was tested on a siliconized release liner. The "template" formulations of the hot melts were discussed with leading suppliers of adhesive raw materials. The goal was to represent a range of standard hot melts available on the market. The starting point was a basic formulation for label applications used as a standard for comparison:

1. SIS polymer with diblock content, plus tackifier based on C5 resin (non-hydrogenated), plus aliphatic plasticizer, plus aromatic phenolic antioxidant

From this basic formulation, individual components were varied one or two at a time for testing, as follows:

2. SIS polymer with no diblock content
3. SBS polymer, tackifier with (25:75) C9/C5 resin
4. SIS polymer with high styrene content
5. SEBS polymer, hydrogenated
6. Tackifier, C9 resin, 100 percent hydrogenated
7. Polymer and tackifier, hydrogenated
8. Rosin ester tackifier
9. Tackifier, (25:75) C9/C5 resin
10. Napthenic oil plasticizer

With this array of hot melts, the impact of the individual adhesive components was investigated in combination with a siliconized liner. (The high-styrene content SIS (#4) did not melt so it could not be tested.)

The release coating is a 70:30 combination of two cold-cure silicones and a 2 percent photoinitiator. Both are silicone acrylates that cure via a free-radical mechanism under UV light. The 70 percent is an easy release silicone, the other an anchoring silicone. The free-radical curing mechanism is robust and unaffected by impurities in the liner material but nitrogen inerting during UV exposure is needed to minimize unwanted oxygen interactions with the silicone. The silicone was coated at approximately 0.9 g/m² and UV-cured in three different ways:

- a) high-dose UV cure (approximately 800 W/cm at 200 m/min.),
- b) low-dose UV cure (approximately 120 W/cm at 200 m/min.), and
- c) curing under extremely high residual oxygen content of 240 ppm.

Even small uncoated areas can contribute to unwanted increases in release forces

as the PSA penetrates pinholes and grabs onto the liner material. Filmic substrates are easier to coat with perfect coverage than paper, so 30 micron biaxially-oriented polypropylene (BOPP) was selected as the release liner material.

The label was stored for six month at 40° C under 70 g/cm² load. Release was then measured with an opening speed of 30 cm/min. at an angle of 180°. In testing the nine hot melts with these three silicone coatings, the importance of the curing conditions became evident.

Interactions at the interface

After laminating, the silicone and adhesive interface may need time to complete the wetting process. With full contact at the interface, van der Waals bonds will develop and contribute to the release force. The development of these bonds may be delayed due to rotation and reorientation of silicone and adhesive polymers. Also entanglement of these polymers at the interface can occur over time. After days or weeks, the orientation processes should be complete, although further increases in release may develop due to the chemical reactions that bridge the interface.

Investigating the hot melts with the three curing variations points to possible causes of these interactions.

Graph 1 shows the release properties of all nine adhesives, each laminated onto a release liner cured with a high dose of UV light. Higher release forces (y-axis) indicate stronger adhesion, and different applications will demand different requirements. Stability over time is what is most important. The data indicate that all the hot melt variations are compatible with RC silicones cured at high-dose UV. Orientation and rotation effects are noticeable with adhesives (7, 8 and 9) at the beginning of the aging test but effects stabilize after some days.

A similar performance was observed on the silicone liner cured with the ultra-low UV dose (see graph 2). Both low- and high-UV dose liners yield comparable release stability, and excess UV does not harm release performance. Of course, a minimum UV dose is needed for full cure of the silicone layer. It is recommended that line speed not exceed 200 m/min. when running only a single 120 W/cm UV lamp.

Cross-linking of the free-radical curing silicones requires inerting with nitrogen to reduce the oxygen level below a 50 ppm threshold to achieve optimal performance of the release coating. UV units used for curing these silicones are designed for a stable window of operation between 10 and 30 ppm oxygen. Above 50 ppm, an automatic control circuit would increase the nitrogen feed and eventually halt production to avoid rejects.

In one trial, residual oxygen content was pushed to a remarkable 240 ppm (see graph 3). Even at this high level, the silicones did not suffer in subsequent adhesion tests (per FINAT #11). The silicone surface on this liner contains excess oxygen by-products, formed due to poor nitrogen inerting. One-day release data show a noticeable increase in release (stronger adhesion) with adhesives (7, 8, and 9).

Adhesives that contain aromatic tackifiers, based on C9 or rosin ester, show an increased release level, and worse, poor release stability. This points to a chemical reaction of these components with oxygen by-products at the silicone layer.

The takeaway is clear. It is critical to maintain the nitrogen blanket to control residual oxygen. An oxygen analyzer should be installed in every siliconizing line to monitor silicone coating quality. If there is no oxygen analyzer available, major problems might be avoided with hot melts that use non-hydrogenated tackifier resins based on C5.

Some UV units are designed to cure UV varnishes or inks under partially inerted conditions. These units may not be sufficient to properly run these silicones, although it may still be possible to produce suitable PSA labels and tapes by adjusting selected adhesive components. For quality adhesive laminates, a properly coated release liner cured with less than 50 ppm oxygen remains key.

These test results contribute valuable information to the development of stable PSA labels and adhesive tapes using hot melts on UV-cured silicone liners. Consistent liner coatings help ensure long-term release stability. In any case, individual tests and trials may be needed to optimize release characteristics.

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Summary of Artwork:

See Excel File

Graph 1 – High-Dose UV Cure

Graph 2 – Low-Dose UV Cure

Graph 3 – Silicone cured at 240 ppm residual oxygen

Other images

A. In-line labelling equipment (ETI Converting photo)

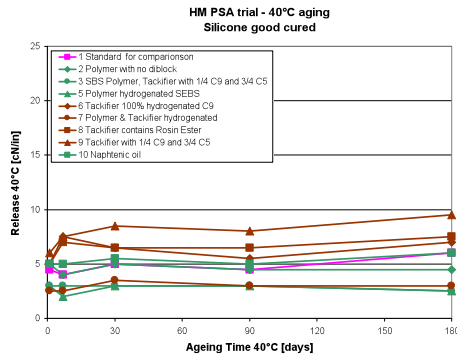
B. Adhesive and Liner Coating: Interactions at the Interface (graph) **Need file**

C. Generic illustration of release coating and label

Release Stability Artwork, Graphs 1, 2, 3

Graph 1 – High-Dose UV Cure

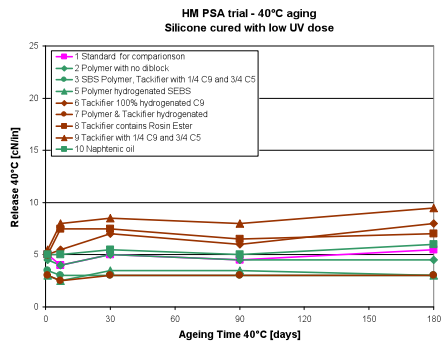
Various Hot-Melt PSAs
on RC Silicone-Coated Release Liner



{Below all graphs}
Aging at 40°C (days)

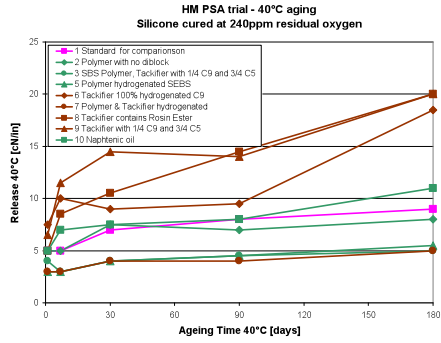
Graph 2 - Ultra-Low Dose UV Cure

Various Hot-Melt PSAs
on RC Silicone-Coated Release Liner



Graph 3 – Silicone cured at 240 ppm residual oxygen

Various Hot-Melt PSAs
on RC Silicone-Coated Release Liner



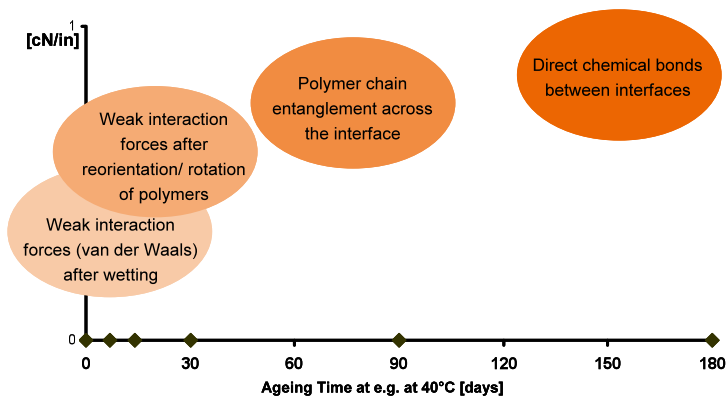
Artwork

A) One-Pass Labeling

This Cohesio multifunctional inline system can print the facestock then coat the liner, apply hot-melt or acrylic adhesive, laminate two webs together and die-cut labels in a single pass. (ETI Converting Equipment, Boucherville, Quebec, Canada)



B) Adhesive and Liner Coating:



Interactions at the Interface

c)

