Conventional and Low VOC Bonding Solutions for TPO Materials

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Abstract

TPO materials, with their low surface energy characteristics, present unique bonding challenges for manufacturers of pressure sensitive adhesives. Add into the equation a second substrate, such as, a foam, vinyl, other low energy surface finish or material and the bonding challenge increases. Adhesive tape construction and the adhesive used play a role in a successfully engineered bonding solution. TPO's engineered for specific applications will require the bonding system also satisfy the requirements of the application. Emerging interest in Low VOC adhesive systems further complicates bonding choices. Automotive interior and other industrial specifications will be impacted by Low VOC adhesive technology. Adchem will explore available adhesive chemistries, the challenges and solutions they provide for the TPO user.

TPO Bonding Issues

TPO materials belong to the larger group of TPE's or Thermoplastic Elastomers. As such they come in many formulations and can be molded into parts with different surface finishes. TPO's (ThermoPlastic Olefins) are copolymers of ethylene, butadiene, and polypropylene which are sometimes extended with oils and are not cross-linked.

The bonding challenges for a PSA, or pressure-sensitive adhesive, to these materials fall into several categories due to the unique nature of the TPO material. These include surface energy considerations, internal contaminants to the bonding process, and surface texture issues.

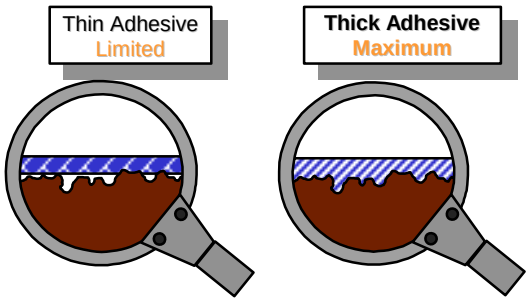
TPO's fall into the category of low surface energy materials which means that pressure-sensitive materials, in general, have a lower affinity for this surface than, for example, stainless steel or glass as evident in Chart #1. Adhesive chemistries must be specifically formulated to ensure appropriate bonding.

Surface Energy by Substrate
(Dynes/cm)

Stainless Steel	400+
Glass	60+
Polycarbonate	52
Epoxy	48
ABS	46
Anodized Aluminum	34
HDPE	34
Fluoropolymer	32
LDPE	32
Rigid PVC	32
Urethane	32
Polyester	30
PP	30
TPO	30

TPO's which are extended with oils may present bonding issues for PSA's if, over time, these oils migrate to the surface and interfere with the adhesive bond. Resistance to this phenomenon is usually achieved through adhesive formulation, heavy caliper or thickness of adhesive or a combination of the two.

The TPO part itself, for design or aesthetic purposes, may be molded with a textured surface. This type of surface can also be problematic for pressure-sensitive adhesives since it depends on surface contact or "wetting" to achieve the appropriate bond. Textured surfaces can require greater pressure, longer dwell times and a higher caliper adhesive construction than smooth surfaces.



Performance Demands:

Technical data sheets for TPO materials talk about such properties as chemical resistance, UV resistance, heat resistance, low temperature flexibility and oil and solvent resistance. Pressure-sensitive adhesives used in bonding TPO materials must also possess these characteristics since a bond failure will translate to a part or component failure.

It is important that the specifics of the "resistance" be communicated to the PSA provider so that the most cost effective bonding solution will be offered. In the world of pressure-sensitive adhesive chemistry, compromises are inevitable. For example, the nature of PSA chemistry is such that it is difficult to offer both high and low temperature resistance in one adhesive. Furthermore, the need for UV, chemical, and/or solvent resistance lean

toward acrylic adhesive chemistry and yet adhesion to low surface energy substrates like TPO's is better achieved using rubber-based adhesive chemistry.

Common Applications and the "Other" Substrate:

If a PSA is required to bond a TPO part, there is typically another non-TPO substrate utilized which may present its own bonding challenges. Common applications for TPO materials include:

Automotive Interior Parts
Automotive Exterior Parts
Appliances
Power Tools
Electrical and Electronic Applications
Sporting Goods
Household Goods
And many others

Using an array of plastic, metal and foam substrates such as:

TPO's
ABS
Powder Coated Surfaces
Urethane Foam
Cross-Linked Polyethylene Foam
Filled and Unfilled Polypropylene
Nylon
Vinyl Nitrile Foam
Aluminum
Acrylic
Polycarbonate
EPDM
Santoprene®
Steel

And more……

PSA's must bond the TPO part to a gasket or other component such as a foam barrier in an automotive HVAC duct. These gasket and foam materials may also be difficult bonding substrates. Chart #2 below shows the wide array of Adchem products that have been tested and bond to TPO materials.

PEELS TEST ON TPO PANELS
180°PEELS @ 12"/MIN; 24HOURS DWELL
Units: Oz. per lineal inch

PRODUCTS	TPO-D162GM/24H	TPO-1402/24H
7434	50 - CP	55 - CP
2237 LINER SIDE	190 - COH	190 - COH
GTW-292 LINER SIDE	80 - FT	105 - FT
4380 LINER SIDE	90 - CP	90 - CP
4352 LINER SIDE	80 - CP	80 - CP
5944 EXPOSED SIDE	65 - CP	75 - 8%COH
MTGL-190 LINER SIDE	40 - CP	55 - CP
4787M LINER SIDE	185 - COH	140 - COH
5008B LINER SIDE	160 - COH	125 - COH
353M LINER SIDE	50 - CP	65 - CP
7854	105 - COH	100 - COH
6181 LINER SIDE	105 - FT	110 - FT
7863	85 - CL/RCH	70 - CP/COH
6940M LINER SIDE	75 - CP	80 - CP
6940T LINER SIDE	75 - CP	80 - CP
6943	80 - CP	80 - CP

Red Font – Rubber Adhesive Chemistry
Black Font – Acrylic Adhesive Chemistry
CP = Clean Peel - No adhesive residue on panel
COH = COHesive – Adhesive splits with residue on test panel
FT = Foam Tear – Foam carrier splitting
RCH = RatCHety peel which is typically between clean peel and cohesive failure.

The above chart consists of acrylic, solvent rubber, and hot melt rubber adhesive chemistries as well as tape constructions double-coated, double-coated foam and transfer or unsupported which reflect the wide array of possible customer considerations to meet their requirements. Understanding the mode of failure is also critical. Clean Peel represents the bonding characteristic of the adhesive to the substrate whereas Cohesive Strength is representative of the internal strength of the PSA adhesive. As demonstrated above cohesive numbers are typically higher than adhesive numbers. In the case of double-coated foam tapes, another limiting factor is the internal strength of the foam which, at sufficiently high peel numbers, results in Foam Tear (FT). This being said, bond strength is "in the eyes of the user" and low peel numbers do not necessarily indicate that the tape system is inadequate. Testing is always the best policy and the numerous bonding studies on foam and non-foam substrates available on Adchem's website can help guide the end user prior to the start of the testing process.

Existing Adhesive Systems.

As depicted in the chart above both adhesive chemistry and tape construction play a role in determining the best bonding solution for the TPO component. Because PSA materials are "converted" before they encounter the TPO part, offering several constructions provides the PSA tape converter maximum latitude in his processing operations. Double-coated tapes with PET carriers permit parts to be die cut into complex shapes and still maintain dimensional integrity. On the other hand, if a flexible gasket must conform to a part with a complex shape, a double-coated tape with a tissue carrier or an unsupported transfer tape might be required. Double-coated foam tapes are employed for special applications such as mounting an automotive antenna base to the glass backlight or rear window.

Even the paper or film release liner requires careful consideration. Kiss cutting operations may require the use of heavy paper board liners whereas high speed rotary die cutting can demand the use of polycoated or film liners. The desire to recycle the discarded liner may also enter into the selection process. The ability of the adhesive tape to release properly from the liner requires special engineering especially with low surface energy materials like TPO's which typically require the use of more aggressive adhesive systems - further complicating the release liner issue. PSA tape manufacturers sometimes devote more R&D resource to the engineering of the release liner - which is ultimately discarded - than to the adhesive itself. Clearly, without an effective release liner, even the best adhesive system is rendered useless.

Adhesive chemistry is equally critical to the success of a TPO bonding system. Adhesive systems are constantly evolving to meet the demands of, not only the newest engineered plastics, but also to constant changes in foams and other substrate materials. Both acrylic and rubber based chemistries can be employed depending on the end use requirements. Acrylic-based systems typically have better UV chemical and solvent resistance but rubber-based systems have more aggressive bonding characteristics and present better economies in most cases. As will be explored later, it is important to understand the total scope of the bonding requirements in order to make an informed selection.

Emerging Technologies.

One of the more recent requirements presented to the pressure-sensitive adhesive manufacturer is the growing interest in Low VOC materials. VOC's or Volatile Organic Compounds are organic compounds that under normal conditions vaporize and enter the atmosphere. They include a wide range of carbon-based molecules, such as aldehydes, ketones, and other light hydrocarbons. The Japanese Ministry of Health, Labor, and Welfare has attracted the attention of several industries by issuing exposure guidelines limiting the detectable limits for 13 VOC's found in confined areas such as homes and auto interiors. Non-existent just a few months ago, requests for Low VOC materials for automobile, flooring, and interior design sources are increasing.

Confusion exists in the world of pressure-sensitive adhesives since no national or worldwide standards have been established. PSA's are called "Low Odor" or "Low VOC" without reference to any guidelines. Our firm has taken the position that for a PSA to be truly called Low VOC it must, at the very least conform to the Japanese MHLW standards which are currently being considered by Japanese car manufactures.

Chart #3 below shows one such system used for the manufacture of a series of tapes for the Low VOC requirement well below the established levels for the targeted VOC's. Although in its early stages, no one can predict what legislative pressures might be brought to bear as interest in the reduction of VOC's grows.

Out Gas Data

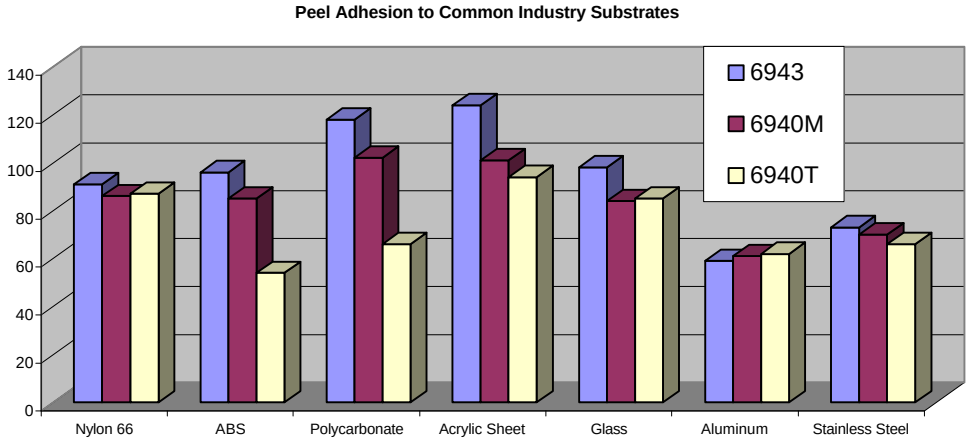
Test Piece Preparations: 66.5g/m2- dry on 50µm of PET film

Out Gas (µ g/m3)	*Below detectable levels* 6940 Adhesive System	*Guide line of MHLW*
Formaldehyde	<1.96	<100
Acetaldehyde	<3.92	<48
Toluene	<0.84	<260
Xylene	<0.84	<870
Ethyl benzene	<0.84	<3800
Styrene	<0.84	<224
Dichlorobenzene	<0.84	<244
Tetradecane	<0.84	<330
Dibutyl phthalate (DBP)	<0.84	<224
Bis(2Ethylhexyl)Phthalate (DE	<1.4	<120
Chlorpyriphos	<0.002	<1
Diazinon	<0.0025	<0.29
Bassa (BPMC)	<1,12	<33

According to JIS A1901:2003

Obviously the best Low VOC adhesive tape system is of limited value if the performance characteristics suffer. In addition to excellent bonding to TPO's as noted in Chart #2, extensive work must be conducted to validate the ability, durability and ease of use for the newly engineered Low VOC series products to bond well to other substrates such as foams (Chart #4) and other common materials (Chart #5).

Foam Bond Evaluation	Dwell Time ?	24Hrs @ RT	24Hrs @ 150F	72Hrs RT	72Hrs @ 150F	7 Days @ RT
Armacell ECF-400 1410RBL	6943	E	E	E	E	E
	6940M	E	E	E	E	E
	6940T	E	E	E	E	E
Foamex LP 180-30CP	6943	G	G	VG	E	VG
	6940M	G	G	VG	E	VG
	6940T	VG	G	VG	E	VG
Foamex Ether	6943	E	E	E	E	E
	6940M	E	E	E	E	E
	6940T	E	E	E	E	E
Foamex Super Seal	6943	VG	VG	E	E	VG
	6940M	VG	VG	E	E	VG
	6940T	VG	VG	E	E	VG
2# Ester UL	6943	VG	E	E	E	E
	6940M	E	E	E	E	E
	6940T	VG	E	E	E	E
1.8# Ether UL	6943	E	E	E	E	E
	6940M	E	E	E	E	E
	6940T	E	E	E	E	E
Ester	6943	VG	E	E	E	E
	6940M	VG	E	E	E	E
	6940T	VG	E	E	E	E
Hybrid	6943	VG	E	VG	VG	E
	6940M	VG	E	VG	VG	E
	6940T	VG	E	VG	E	E
7# PVC	6943	G	G	G	G	G
	6940M	G	G	G	G	G
	6940T	G	G	G	G	G
Vinyl Nitrile	6943	VG	VG	VG	E	VG
	6940M	VG	VG	VG	E	VG
	6940T	VG	VG	VG	E	VG



In addition to very good bonding to TPO materials, and despite the radical departure from commonly employed chemistries, this new technology has shown wide ranging adhesive versatility.

The Selection and Evaluation Process:

The more we know about the application and processing needs, the more likely we are to be able to recommend and supply the most cost effective solution. TPO's are highly engineered for demanding applications which means that if a PSA is needed, the same demands will be placed on the bonding system. Detailed application, environmental performance, specifications, shaping methods and life cycle information are required to design and specify the correct and cost effective tape system.

To elaborate, we must determine what the adhesive has to do within the environment in which it will function. Knowing the temperature ranges and operating conditions as well as exposure information will prevent unnecessary or premature failures. The presence of UV and some chemicals can degrade certain adhesive systems. Although many industries develop specifications to assist with the selection process, these specifications sometimes do not account for all "real world" application conditions or may not take into account recent developments in PSA chemistry. Part geometry plays a role in the selection of the appropriate PSA from both the chemistry and tape construction as was noted previously.

Other material specific performance requirements come into play especially when TPO's are involved. For example, what grade of TPO is being used and is it extended with oils? What about the other surface? Plasticizer resistance? Low fogging and, more recently, Low VOC? The surface conditions of some molded TPO parts and some foam materials may warrant the use of heavier caliper adhesive systems.

Processing issues cannot be ignored and liner release and liner processing parameters must be established. This requires the cooperation and interaction of the end user, the converter and the PSA supplier.

Conclusion:

TPO materials are a unique grade of engineered plastics offering key properties for the designer of parts to improve products in a wide variety of industries. Many of these parts will require the use of a pressure-sensitive adhesive as part of the final product assembly. Those requirements, coupled with new demands for product performance such as Low VOC materials, provide the PSA supplier the opportunity to be a developmental partner with the molder and provider of TPO components. Any changes in the base material of a part, whether due to price pressures, recycle-ability, or other considerations will dictate a re-evaluation of the PSA used in the new part.