ADVANCES IN ACRYLIC EMULSION PSAS FOR USE WITH FOAM CARRIERS

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Abstract

Foam tape designers have historically relied on solvent borne pressure sensitive adhesives (PSAs) for high performance applications such as mounting, vibration damping and construction. Recent advances in polymerization technology have led to acrylic emulsion PSAs which match solvent acrylic and synthetic rubber adhesives for several properties such as good anchorage to low and high density polyolefin foams. This modified water borne technology also delivers the excellent balance of PSA properties and resistance properties (heat, humidity, plasticizer) required for many foam tape applications. This paper presents a brief overview of various foam tape characteristics and end uses, with a focus on the advantages of these new acrylic emulsion PSAs in combination with the more common foam types.

Introduction

One of the more interesting and challenging classes of pressure sensitive tape products are those based on flexible foam backings. Foamed thermoplastics offer a range of features which provide performance characteristics unachievable with other types of tape backings. (See Table 1). In addition, the unique modulus of flexible foams can work in conjunction with a PSA to enhance adhesive performance by absorbing stress on the adhesive joint.

Table 1. Foam tapes with various backing materials

FOAM TYPE	ADVANTAGES	DISADVANTAGES	TYPICAL USE
Polyolefin	low moisture transmission, gauge control, low cost	adhesive anchorage	window glazing, appliances, mounting, medical
Polyvinyl chloride	weather resistance, low compression set	plasticizer migration	sound damping, gasketing, medical
Acrylic	excellent aging, modulus	cost	automotive mounting, construction, structural
Polyurethane	gap filling	water absorption	mounting, gasketing, lens grinding, damping
EPDM	heat, water resistance, energy absorption	adhesive anchorage	sealing, damping
Silicone	high temperature, dimensional stability	adhesive anchorage, cost	aero insulation, sealing

A number of performance features are required from the pressure sensitive adhesives used in foam backed tapes. Solvent acrylic and solvent rubber PSAs have provided the range of properties needed for these high performance tapes, but recent advances in emulsion acrylic technology are leading to next generation products able meet the demands for excellent performance without the disadvantages of solvents.

Several aspects of performance improvement in these new emulsion acrylic PSAs will be reviewed, including environmental resistance, anchorage to polyolefin foams, low surface energy adhesion, and plasticizer migration resistance.

Heat and Humidity Resistance

Foam mounting tapes require not only the correct balance of traditional PSA properties; they also need good environmental resistance. Acrylic polymer films formed from conventional emulsion polymers have suffered from lower performance in high humidity environments compared to their solvent-borne counterparts. Improvements in this area were required to expand the use of emulsion PSAs into foam mounting tape and other high performance applications.

An emulsion polymer in the wet state consists of discrete polymer particles stabilized by surfactants. The hydrophobic surfactant “tail” associates with the polymer particle and the hydrophilic surfactant “head” orients with the aqueous phase. Although critical to emulsion stability, mobile surfactant which stays with the polymer after drying and film formation and is present at the interface of the particle boundaries may result in diminished performance. See Figure 1. Surfactant concentration and type both impact final film properties. The polymer chemist must balance polymerization surfactant requirements with wet state emulsion stability and performance characteristics of the dried film.

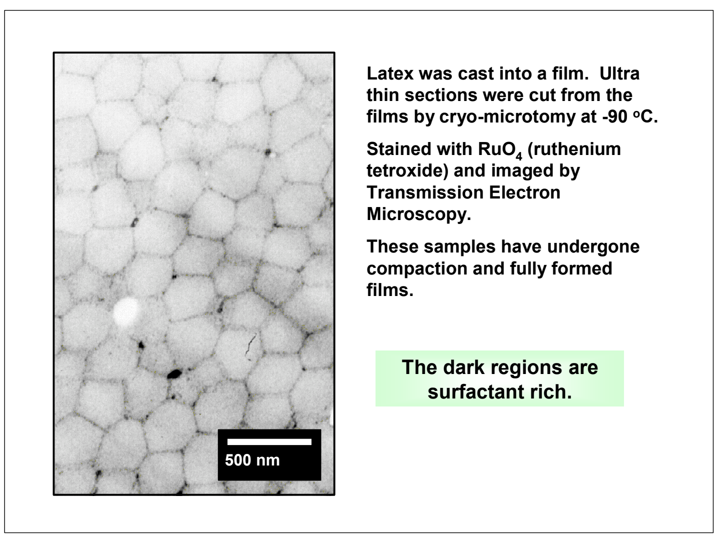

Figure 1. Transmission Electron Microscopy image of surfactant adsorbed at particle boundaries

Recent advances in surfactant technology combined with better understanding and control of polymer particle morphology have resulted in acrylic emulsion polymers with outstanding resistance to high heat and humidity environments. The nanotechnology shown in the Figure 2 has been successfully employed to produce tighter polymer films that deliver the PSA properties and resistance requirements for high performance foam tapes.

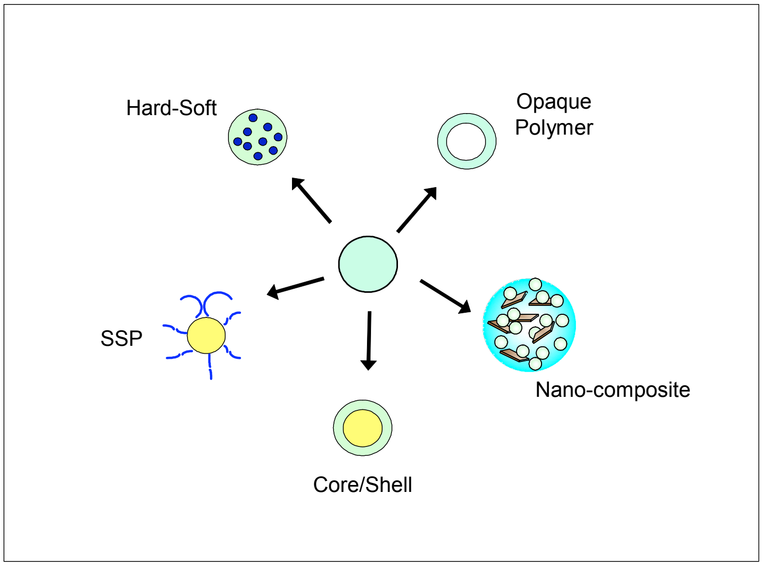

Figure 2. Acrylic polymer particle morphologies

To demonstrate the improvements in humidity resistance, two emulsion PSAs were synthesized, one incorporating the new technology and the other as a control. These were coated onto 50 micron polyester film at a dry coat weight of 50 gsm. One inch wide strips were cut and applied to stainless steel (SS) panels. The panels were either stored at 23°C, 50% RH, or at 36°C, 99% RH. The samples were removed from the environment and immediately tested for 180° peel adhesion. Results are shown in Table 2. Additional accelerated aging tests on the emulsions also indicate excellent shelf stability for these one pack systems.

Table 2. Humidity Resistance of Modified Emulsion Polymer
180° Peel Adhesion, SS

	7 days, 23°C, 50% R.H pounds/inch (Newtons/25.4 mm)	7 days, 36°C, 99% R.H pounds/inch (Newtons/25.4 mm)
Modified	5.6 (25)	7.5 (33)
Conventional	5.4 (24)	0.1 (0.4)

Anchorage to Polyolefin Foam

Many foam mounting tapes are produced using closed cell polyolefin (PO) foam backings. PO foams are available in a wide range of densities, surface treatments and compositions. Due to their low surface energy and high cross-link density, obtaining good PSA anchorage to the foam can be challenging.

While aggressive rubber based PSAs anchor well to PO foam, these are not suitable for some demanding applications due to requirements such as high temperature resistance and environmental exposure.

To produce foam backed PSA tape, the liquid adhesive may be coated directly onto the foam and dried. Alternatively, transfer tape (a free film of dried adhesive on siliconized release liner), or double coated tape (a film carrier coated on each side with PSA), may be laminated to the foam. Obtaining anchorage to the foam can be difficult in both cases, with the indirect (laminating) method being the more problematic.

Solvent acrylic PSAs are used successfully for these applications, with two techniques being employed to achieve good anchorage to PO foam: corona treatment of the foam prior to adhesive coating and the addition of tackifying resin to the acrylic polymer. However, these approaches are often insufficient when used with traditional emulsion acrylic PSAs.

Recently, emulsion acrylic PSAs with excellent anchorage to cross-linked PO foam have been produced by combining novel polymer adhesion promoting technology and special tackification techniques. Failure mode during peel adhesion to SS is one indication of anchorage level, with failure mode changing from AFB (adhesive failure to backing) to adhesive failure from the SS panel indicating improvements in anchorage. In addition, subjective, manual adhesive face-to-face anchorage testing is commonly used. With proper pass and fail controls this method can also provide valuable comparisons.

Emulsions were synthesized using standard methods and no adhesion promotion technology while another set incorporating nano-structures and novel adhesion promoters were made. These emulsions were transfer coated at 50 micron dry adhesive thickness to Volara® EO and TS foams. The foam/adhesive constructions were cut into one inch wide strips and then adhered to stainless steel panels. After a 30 minute dwell time at 23^{o}C, a 90^{o} peel adhesion test was performed. Table 3 indicates that PSAs prepared using the new technology exhibit anchorage and adhesion high enough to cause a foam tear type failure on both foam types.

Table 3. Improved Anchorage to PO Foam with Modified Emulsion Polymers

Volara® Foam Type	Emulsion Adhesive	Failure Mode	90^{o} Peel Adhesion, SS, pounds/inch (Newtons/25.4 mm)
EO	Modified	Foam Tear	6.5 (29) peak
EO	Conventional	Adhesive to Foam	3.0 (13)
TS	Modified	Foam Tear	5.9 (26) peak
TS	Conventional	Adhesive to Foam	2.6 (12)

Low Surface Energy (LSE) Adhesion

The proliferation of plastics with low energy surfaces has generated the need for PSA tapes with good adhesion to these materials. Typical materials of interest include polyethylene, polypropylene, talc filled polypropylene, surface polished polyolefin, powder coated metals, high tech automotive or factory applied paint systems. For foam mounting and foam gasketing products, adhesion values to these LSE materials sufficient to result in foam failure (tear) rather than adhesive failure (clean peel) during peel testing is often desired.

Acrylic PSAs generally require the incorporation of tackifiers to facilitate flow, modify polarity, and achieve this level of adhesion. However, higher and higher tackifier levels to work with increasingly difficult surfaces eventually results in a zippy or slip stick failure mode and a system that is not suitable for the application.

However, high peel values from some of the most difficult LSE materials have now been achieved in emulsion acrylic PSAs by combining novel polymer design and adhesion promotion technology. Results in Table 4 demonstrate the dramatic improvements possible with these advances. These results are unique in their smooth (non-zippy) peel response and their high peel values.

Table 4. Improved Adhesion of Modified Emulsion Polymers to Low Energy Surfaces
180^{o} Peel Adhesion

	Lens Finish PP pounds/inch (Newtons/25.4 mm)	Talc Filled PP pounds/inch (Newtons/25.4 mm)
Modified	5.5 (24) smooth	6.0 (27) smooth
Conventional	1.0 (4) zippy	1.5 (7) zippy

Polyvinyl Chloride (PVC) Foam Tapes

Flexible PVC foam is lightweight, easily fabricated, weather-resistant and remains flexible under wide temperature ranges, making it a versatile backing for pressures sensitive tapes. Applications include gasketing material to seal water and air from entering joints, protective cushioning, vibration and noise damping in industries such as automotive, electronic, construction, HVAC and medical.

Formulations for producing PVC foam include many low molecular weight additives, including plasticizers. PSAs in contact with this type of foam backing must be designed with good plasticizer migration resistance (PMR) to prevent these ingredients from moving across the adhesive/foam interface and entering the adhesive mass. Synthetic rubber based PSAs based on styrenic block polymers are generally not recommended for these types of products. Solution acrylic PSAs on the other hand have enjoyed success in these constructions.

Emulsion acrylic PSAs suitable for lower performance PVC foam products (ones with low peel/tack levels, and/or short service life, and/or no exposure to harsh environments) are currently in use. But the ongoing drive away from solvent use has created the need for emulsion acrylic PSAs with PMR properties sufficient to work in more and more demanding applications (high tack products using flexible foams with high plasticizer concentration and long service life requirements).

Automotive is one example of an industry which expects high performance from economically priced tapes. Many manufacturers specify the PVC foam tapes used in gasketing or sound deadening to pass heat age testing, and solvent acrylic PSAs have historically been required to meet these specifications. A typical screening method involves bonding the tape to a stainless steel panel, exposing the assembly to high temperature, e.g., 70^0C for seven days, and testing peel adhesion after a cool down period. Foam tear failure mode is the required result.

At elevated temperatures the rate of plasticizer migration is increased and traditional water based PSAs fail cohesively or at the adhesive-foam interface. Subsequent surface analysis reveals high levels of plasticizer in the bulk adhesive as well as on the exposed surfaces of both the adhesive and the foam.

High peel acrylic emulsion PSAs have recently been developed which incorporate state of the art modifications to the polymer composition, and which are capable of performing well on highly plasticized foams in harsh environments. Figure 3 shows results of this new technology (foam failure) compared to traditional emulsion acrylic PSA (failure at adhesive-foam interface) in Figure 4.

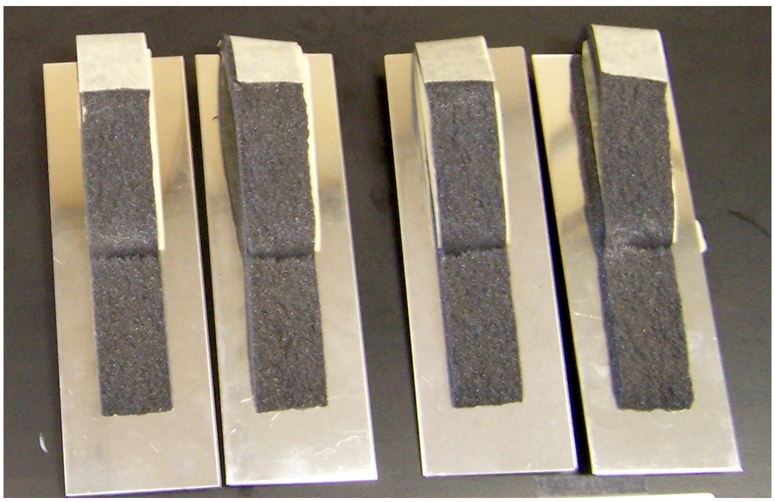

Figure 3. Plasticized PVC foam tear with modified emulsion PSA after automotive aging test (7days @70C)

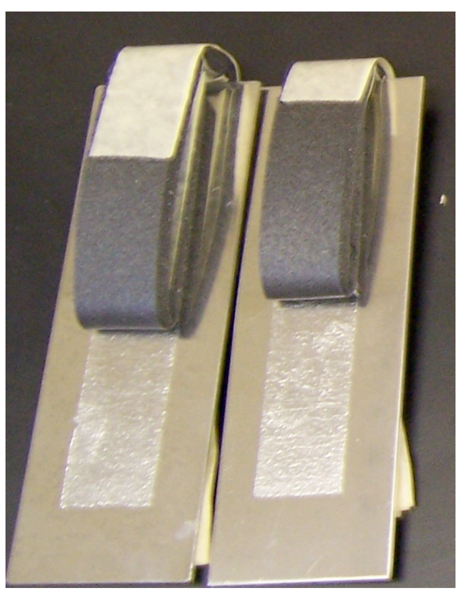

Figure 4. Adhesive failure to plasticized PVC foam with commercial aqueous PSA technology after automotive aging test (7days @70C)

Summary

With the recent technology advances described above and the global drive to reduce the use of hydrocarbon solvents, emulsion acrylic PSAs now offer foam tape manufacturers an economical and environmentally friendly alternative. With escalating oil prices, increasing environmental concerns and more value being required of all products, next generation water borne adhesives are an important option.

Acknowledgments

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Thomas Reffle is a senior technical service chemist who has been supporting the specialty tape market segment for the last nine years. His areas of expertise include both acrylic and synthetic rubber based pressure sensitive adhesives. Reffle joined Rohm and Haas Company in 1990, first working on polymer R&D for the flooring and construction adhesive industry. He holds several academic degrees including a Bachelor of Science degree in chemistry (summa cum laude) from Delaware Valley College of Science and Agriculture. Reffle is currently a Ph.D. student in polymer chemistry at Drexel University in Philadelphia.