

Pressure Sensitive Adhesives in High Performance Applications

Michael J. Zajackowski

Avery Dennison Performance Polymers Division
Mill Hall, PA USA

Introduction

The use of pressure sensitive adhesives in high performance applications has been increasing due to advances in rubber, silicone, and acrylic technologies. Some of these high performance applications are in electronics, where PSAs are used in the manufacture of computer disk drives, and in the medical industry, where PSAs are suitable for skin contact and transdermal drug delivery. High performance automotive and construction applications include the mounting of body side molding on automobiles and the construction and sealing of HVAC air duct and connector systems.

Some PSA technology advances include utilizing a silicone-urea backbone in place of the traditional peroxide cured silicone gums in silicone PSA formulations and tailoring acrylic backbones to be compatible with and influencing the release of drugs in transdermal drug delivery devices. Another advance is the grafting of rubber moieties to an acrylic backbone to increase compatibility with non-polar tackifiers to enable low surface energy bonding.

Despite these advances, there is still a need for improved bonding characteristics of PSAs at low temperatures and increased bonding to low surface energy substrates while maintaining high cohesive strength and temperature resistance. It would be particularly advantageous to be able to achieve this performance in a predominately acrylic system due to the inherent cost-benefits of acrylic PSAs.

Background

Solution Acrylic Polymerization Technology

Predictions from the 1970's and 1980's have not materialized, specifically, the decline of solvent borne PSAs. Emulsion, hot melt, and UV-curable materials were believed to be on the verge of producing performance approaching that of many solvent PSAs. However, the continued need for high performance and excellent coatability coupled with the relative price stability of monomers and solvents have enabled the continued growth of solvent PSAs.

Factors which influence acrylic PSA performance include:

- Monomer Composition of the Acrylic Backbone
- Functionality on the Acrylic Backbone
- Polymer Molecular Weight and Branching
- Crosslinking
- Formulation

Effect of monomer composition- Choice of base monomer for an acrylic PSA will influence hydrophobicity, glass transition temperature (T_g), and moisture and oxidative resistance of the polymer backbone. Some common low T_g base monomers include 2-Ethylhexyl Acrylate, Isooctyl Acrylate and Butyl Acrylate. These "soft" base monomers are typically the most abundant monomers by weight in an acrylic PSA formulation and are responsible for the inherent tackiness of the PSA.

Modifying medium Tg monomers include Methyl and Ethyl Acrylate, Vinyl Acetate, and Isobutyl Acrylate. High Tg modifying monomers include Isobornyl Acrylate and t-Butyl Methacrylate.

Functional Groups- Carboxylic acid or hydroxyl functionality can be incorporated into the adhesive backbone during the polymerization by utilizing acrylic acid or hydroxyethyl acrylate monomers respectively. Acrylic acid is a high Tg monomer that, in addition to increasing cohesive strength, provides a polar moiety for bonding to polar substrates like metals. Hydroxyethyl acrylate is also a polar monomer, but has a moderate Tg. Both acrylic acid and hydroxyethyl acrylate provide sites for crosslinking. Additional functional groups that can be incorporated during polymerization include epoxy and anhydride.

Polymer Molecular Weight and Branching- Generally, increasing molecular weight improves cohesive strength while reducing peel adhesion. For a given composition, the molecular weight distribution of the acrylic polymer must be optimized to obtain maximum performance. Higher Tg compositions require a relatively low molecular weight in order to maintain the ability to wet a surface. Softer compositions require higher molecular weight in order to display adequate cohesive strength.

A polymer with a high degree of branching will display higher adhesion while maintaining an equivalent cohesive strength compared with a polymer with a more linear backbone. This can be attributed to the additional chain ends, which aid in the ability to wet a surface.

Crosslinking- Crosslinking increases cohesive strength, temperature and solvent resistance. The improvement in strength comes at the expense of adhesion. The crosslinking can either be covalent or ionic (metal chelate). The former imparts better temperature resistance and the latter is convenient as crosslinking is accomplished upon solvent removal without the need for additional heat.

Formulation- Acrylic PSAs can be further formulated with tackifiers, fillers, and antioxidants to enhance properties. Tackifiers can increase adhesion especially to non-polar surfaces. This improved adhesion comes at the expense of cohesive strength. Fillers can provide increased thermal conductivity or flame resistance.

The above discussion outlined factors that influence PSA performance. It now has been demonstrated that higher performance can be achieved by utilizing polyacrylate and polyether backbones in the same system to form an Interpenetrating Network (IPN).

The blending of the acrylate and polyether components accomplishes the following:

- *Control of crosslink density-* Blending the PPO oligomer with the acrylate polymer imparts an additional level of control on polymer architecture. Independent of the acrylic backbone, the oligomer crosslinks to form a network. This network forms a tough rubbery material, which increases the strength of the acrylic polymer. If the acrylate polymer contains silane functionality the oligomer will also bond to the base polymer. The extent the oligomer derived network reacts with the acrylic base polymer depends on the concentration of silane functional groups in the acrylate backbone. Crosslinking the PPO oligomer in the presence of the base polymer produces an interpenetrating network (IPN).
- *Polarity-* The PPO oligomer adds a non-polar characteristic to the relatively polar acrylate backbone.
- *Glass Transition-* The PPO oligomer lowers the Tg of the acrylate portion without sacrificing cohesive strength due to the crosslink density imparted by the oligomer. The resultant lower Tg of the polyether-polyacrylate system enables lower temperature bonding.
- *Formulation-* The PPO oligomer is compatible with many common tackifiers. This enables tackified PSA formulations to maintain high cohesive strengths.

Polyacrylate-Polyether Formulations

The first requirement for producing the polyacrylate-polyether PSA is to ensure the base polymer is compatible with the oligomer. The photo below (see Figure 1) shows the acrylic polymer above and a traditional solvent based PSA blended with 30% PPO oligomer on acrylic polymer solids.



Figure 1

The bottle on the right (Standard Solvent PSA) is not entirely compatible as evidenced by the haze. The acrylic base polymer formulated for compatibility with the SAX 725 is clear.

Properties of Polyether-Polyacrylate IPN Pressure Sensitive Adhesives

An IPN based Pressure Sensitive Adhesive formulated with the components discussed above consists of a base polymer, which contains crosslinking sites on the backbone, a metal chelate compound for crosslinking the base polymer and catalyzing the silane functionality on the oligomer and acrylic backbone. A terpene phenolic tackifier is included to increase adhesion

Heating, Ventilation and Air-Conditioning Foil Tape Construction

The above data demonstrates the utility of the polyacrylate-polyether IPN pressure sensitive adhesive. One potential application for this technology is as a pressure sensitive adhesive for an aluminum foil tape construction for use on HVAC Duct Board. When the foil tape is applied and allowed to build to its ultimate adhesion, the adhesive tape de-laminated the aluminum sheet from its backing. See Figure 2.

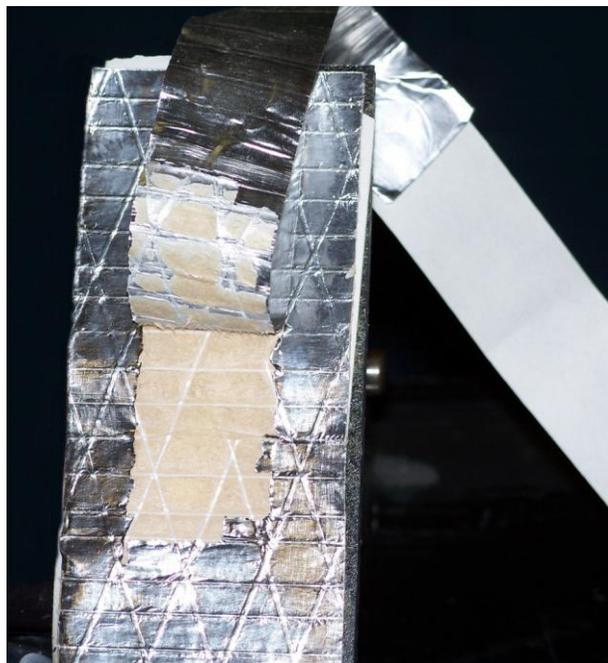


Figure 2

HIGH STRENGTH PRESSURE SENSITIVE ADHESIVE

Effect of Aluminum Trihydrate

The polyether-polyacrylate technology can further be modified to increase strength by adding Aluminum Trihydrate (ATH). A 0.25 micron particle size Aluminum Trihydrate (S-11, sold by Almatix, Inc.) was added to the polyether-polyacrylate PSA above, and an increase in cohesive strength occurred. This reinforcement presumably is an outcome of the interaction between the silane components in the PSA and the inorganic filler. The designation for the filled IPN PSA is S8756.

FUTURE WORK

Although the ability to bond to olefin substrates has been demonstrated, increased bond strength to low surface energy surfaces can be accomplished by reducing the polarity of the base polymer backbone. Additionally, the positive interaction between the polyether-polyacrylate PSA and inorganic particles makes this technology suitable for high performance applications where fillers add to the functionality of the adhesive. Such applications include adhesives for automotive electronics where thermal, chemical, and electrical resistance is required.

CONCLUSIONS

Utility in existing applications has been demonstrated, particularly for the manufacture of foil tapes. In addition, the systems which contain inorganic fillers display extraordinary cohesive strength. This property will enable the filled PSA system to accept soft components (ie. Plasticizers) and perform at a high level. This attribute will be important when formulating liquid flame retardants such as phosphate esters to produce non-halogen containing flame resistant pressure sensitive adhesives.

Avery Dennison currently supplies two IPN Pressure Sensitive Adhesives: S8755 and the Aluminum Trihydrate containing S8756.