



Pressure Sensitive Adhesives

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INTRODUCTION

A pressure sensitive adhesive (PSA) is one that can be made to adhere satisfactorily to a surface by light pressure. Commercial PSAs are complex mixtures of polymers, tackifiers, stabilizers, etc.

In general, PSAs are highly viscoelastic, their mechanical properties strongly dependent on strain rate or frequency. The viscoelastic behavior of PSAs is a major factor in their performance. Figure 1 shows the behavior of a typical natural rubber-based PSA with the mechanical response as a function of frequency. The approximate strain rates encountered in typical operations associated with the manufacture and end use of pressure sensitive household tapes are shown for reference. Application rates for tapes are found around 1 s^{-1} . Bond strength, the performance parameter is tested using a peel or tack test. The peel test is a debonding test at high shear rates, the tack test is performed at lower rate. The cohesive strength

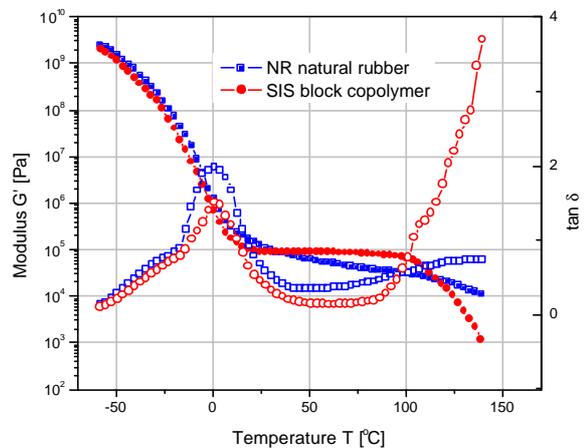


Figure 2: Temperature dependence of a PSA

of a PSA can be measured in simple shear, a creep test for most of the time. In order to function well in this application, a PSA should have an elastic (storage) modulus (G') between 2×10^4 and 2×10^5 Pa at 1 rad/s at application temperature.¹ This allows sufficient deformation for good flow into a new substrate in short contact times. Yet it is sufficiently rigid and has low creep at long times.

BLOCK COPOLYMERS AND GLASS TRANSITION

The dynamic mechanical properties of polymers measured on a rheometer as a function of temperature are important factors in deciding their usefulness in pressure sensitive adhesive applications. Many PSAs are block copolymers, such as styrene-elastomer-styrene copolymers. The dynamic mechanical properties of a styrene-isoprene-styrene copolymer and a natural rubber for PSA applications are plotted in figure 2. The

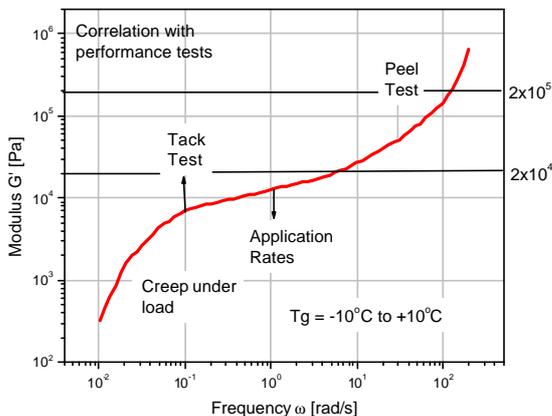


Figure 1: Performance- frequency relation for a PSA

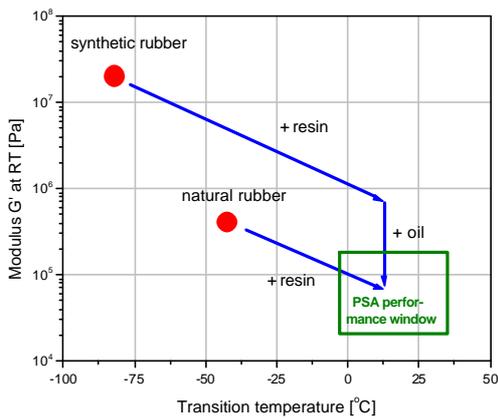


Figure 3: PSA performance window

elastic modulus (G') exhibits a plateau region between the two domain glass transitions. The height of this plateau is governed mainly by the shape and size of the glassy domains of the polystyrene. Two glass transition temperatures are seen due to the two-phase structure of the block copolymers.

PSA performance is dependent upon the glass transition temperatures of the adhesive constituents relative to the expected use temperatures and the storage modulus at use-temperature. For room temperature PSAs, a glass transition temperature of about -15°C to 5°C offers good adhesive performance. The G' value is approximately $100\,000\text{ Pa}$ for the household tapes shown in figure 2.

For most elastomers, the storage modulus at room temperature is higher. By adding compatible tackifying resin or oil, the G' value is adjusted. The addition of compatible resin reduces the storage modulus at use temperature, but also shifts the low temperature rubber

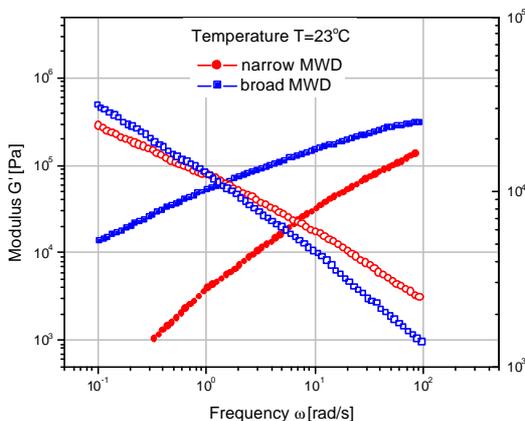


Figure 4: Latex pressure sensitive adhesive

transition to higher temperatures. The oil only reduces the modulus, because of its very low transition temperature. Using this procedure, any suitable rubber can be formulated to become a PSA as shown in figure 3.²

LATEX PSAS AND MOLECULAR WEIGHT DISTRIBUTION

For latex PSA applications, the molecular weight distribution is an important consideration. Elastomers with broad molecular weight distributions typically show better performance than materials with narrow molecular weight distributions. The concept of tackifying resins functioning as solid solvents for portions of the elastomer has been used for many years to explain the need for a broad molecular weight distribution. Figure 4 shows the differences in dynamic behavior of two PSAs with different molecular weight distribution. Without the correct molecular weight distribution, the desired balance of tack and strength cannot be obtained.

SOLVENT AND WATER-BASED ADHESIVES

Solvent- and water-based adhesives are often applied using techniques that have complex flow characteristics. Careful analysis of the flow properties of these dispersed adhesives is required to ensure proper application. Spraying, roller coating, and calendaring are three of the techniques used to apply adhesives to a surface. Wood, plastic, and paper are possible substrates. Rheological measurements are often used to analyze flow problems that occur with these coating processes.

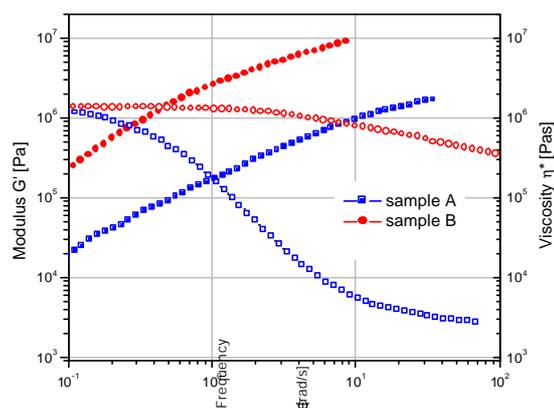


Figure 5: Water based spray adhesive

An adhesive must flow easily upon leaving a spray gun or roller and then remain smooth and drip-free as soon as it is applied to the surface. Complete and uniform coverage are required. Acrylic polymer cements dissolved in volatile solvents as well as vinyl acetate latex formulations—the common “white glue”—are two examples of solvent- and water-based adhesives.

The application characteristics of an adhesive coating can be predicted by monitoring the elastic modulus (G') and the viscosity (η^*) versus frequency. As shown in Figure 5, these rheological data can distinguish between good and poor water-based spray adhesives. Sample A's viscosity decreases drastically with increasing frequency, as compared to Sample B. This is an example of shear thinning behavior. Shear thinning is desirable for an adhesive so that it forms a uniform coating during application. In fact, Sample A did apply uniformly, while Sample B was uneven during application.

PROBE TACK

A pressure-sensitive adhesive (PSA) is one that adheres instantaneously to most solid surfaces upon application of a light pressure to the adhesive film. This behavior is a consequence of the adhesive being permanently “tacky.”

One method of measuring PSA tack is the probe tack test defined by ASTM test D 2979-77. The test employs a cylindrical steel probe (type 304 stainless steel) 5.0 mm in diameter

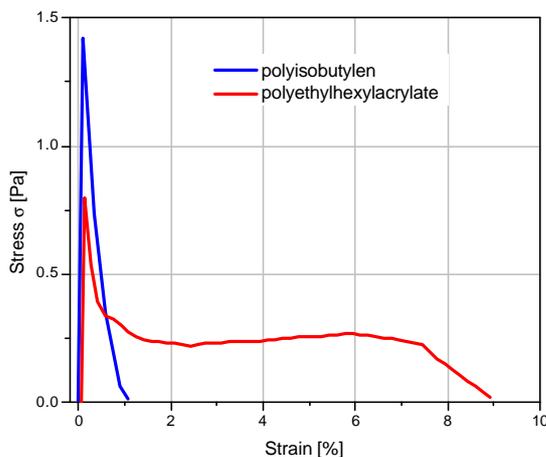


Figure 6: Stress-strain curve for two different adhesives during a tack test

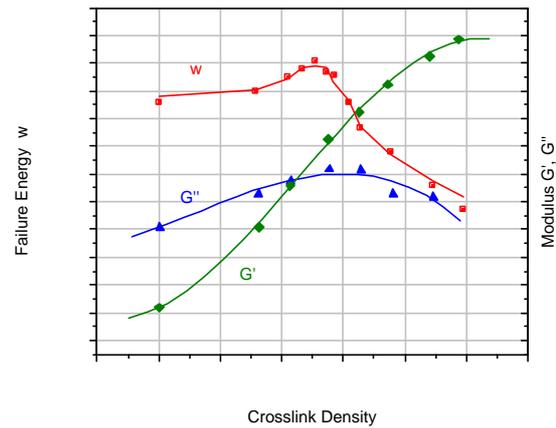


Figure 7: Adhesive failure Energy (w) and G'' versus crosslink density for a siloxane adhesive

machined at one end 90° to the longitudinal axis. The probe is brought in contact with a PSA film at a fixed stress (usually 10 kPa) for one second, then removed at a constant rate. The maximum force to pull the probe away is recorded, and this maximum force is defined as the sample's tack.

Using the linear testing modes of the ARES and RSA rheometers and the appropriate tack fixtures, tack tests can be easily and accurately performed. Besides measuring the maximum force with increased precision, the entire stress versus displacement (strain) history during the probe-PSA contact is recorded. Figure 6 shows the stress-strain curves obtained for a polyisobutylene and a polyethylhexylacrylate adhesive. From these the energy to failure can be calculated directly.³

Zosel⁴ showed on polydimethylsiloxane (PDMS), a crosslinking system, that the failure energy w - the area under these stress-strain curves - is a much more sensitive measure of tack compared to using the height of the peak (maximum force) in the simple ASTM test. The adhesive failure energy w in figure 7 correlates well with G'' (the loss modulus) measured at 1 rad/s. Zosel also reported that peel strength had a strong maximum just past the gel point.

CONCLUSION

Rheological measurements can provide useful information for processing, product development, and application of adhesives. Practical parameters such as good flow, quick drying,

complete coverage, and long term adhesion can be related to rheological properties. Tack tests can be performed on any rheometer with linear test modes and the energy to failure calculated to evaluate the tack performance of an adhesive.

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