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Pressure sensitive adhesive basic

Take your discussion with your PSA provider to the next level

A very successful converter of medical tapes asked how adhesives worked and what made one different from the next. This question, from an expert in the application of medical tapes, was a great reminder that it's sometimes good to return to the fundamentals and ensure producers and users of medical tapes are speaking the same language. Too frequently, adhesive vendors use descriptions such as 'tackified acrylic' and discuss 'plasticizer migration' as though the concepts are universally understood. If you're not sure what makes something 'sticky', read on.

In this article we'll attempt to decipher some of the terms used every day by pressure sensitive adhesive (PSA) experts. If successful, by the end readers will have a better understanding of PSAs, more appreciation for their complexity and acquire a basic vocabulary to have more meaningful discussions with their adhesive providers.[2]

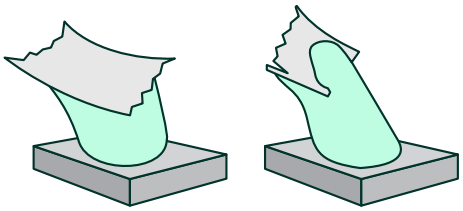
The primary component of a PSA is a polymer. For our purposes you may simply picture polymers as very tiny strings. Though tiny, they are long enough to get tangled up with each other and it's the degree of entanglement that determines many of a bulk polymer's features. Two of the primary handles an adhesive developer has to manipulate the properties of the adhesive are how stiff and how long our imagined strings are. Very flexible polymers, generally having softening points below 0 °C, are used to make PSAs. For comparison, the acrylic polymer from which plexiglass is made has a softening point over 100 °C.

At room temperature, our tangled strings are well above their softening point, and thus there is a lot of motion at the molecular level. At the application temperature of a PSA, its chains are bending, twisting, and sliding past one another. It's the chain entanglements that prevent a layer of PSA from flowing like a liquid. Over time, this molecular movement has consequences on the microscopic and even the macroscopic scale.

A PSA expert we know says a PSA needs only two things: 'guts' and 'grip'. 'Guts' refers to internal (cohesive) strength. If half the adhesive remains on the substrate when a tape is peeled away, the adhesive lacks cohesive strength. The major contributors to cohesive strength are polymer chain length and chain-chain interactions. The longer the polymer chains, the more opportunity there is for entanglement. Polar and acid-base interactions between polymer chains slow their movement past each other and aid cohesive strength. The ultimate chain-to-chain interaction is a chemical bond, referred to as a crosslink that 'ties' the chains together. Longer chain lengths, chain-chain interactions and crosslinks all reduce the mobility of adhesive polymer chains. Reduce the mobility too far and you have a poor PSA.

The 'softening point' of a polymer is the glass transition temperature (Tg). As a polymer is heated, the Tg is the temperature at which it stops behaving like a rigid glass and begins to take on the squishy/rubbery character it has at higher temperatures. Suffice it to say that squishy (viscous, energy dissipating) and rubbery (elastic, energy storing) behaviors are the two halves of the viscoelastic nature of polymers found in PSAs.

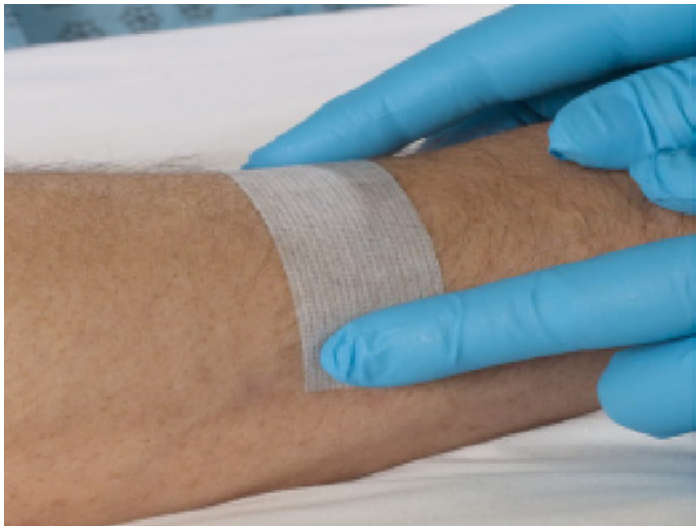
'Grip' is what most people are referring to when they say 'adhesion' – how well the adhesive bonds to the substrate. Pressure sensitive adhesives don't form chemical bonds with the substrate, whether that's steel or skin. They bond with the substrate through molecular-level interactions. These interactions can be relatively strong, like acid-base pairing or among the weakest forces in chemistry, the dispersive force between two hydrocarbons induced by the random motion of electrons. All PSAs need to be molecular-level close to the substrate in order for these interactions to take place. This is why it's critical that PSA polymer chains (our strings) are bending and twisting at the molecular level. A quick thought experiment: Picture a two-inch-long string dipped in water and frozen in a curved shape. Imagine the ends of the string are where it is tangled with the bulk of strings comprising our layer of adhesive. Now hold the ends a half-inch above a tabletop so the string is curved away from the surface. If that's a polymer chain, it is much too distant for any interaction with the atoms or molecules comprising our substrate (the tabletop). Now melt the ice. The string falls into contact with the table and interactions begin, making it energetically unfavorable for the string to lift from the table, or a polymer chain to separate from a substrate. Reproduce this effect billions of times in a PSA and you have adhesion between the bulk of the adhesive and the substrate.



Deformation of a pressure sensitive adhesive (light teal) prior to its debonding from the substrate (gray) during peel.

The term wetting derives from this process of adhesive chains coming into close contact with a substrate and interacting with it. You can apply an adhesive to a surface, but if it doesn't wet out, it can't adhere. A common misunderstanding regarding pressure sensitive tapes is that the final bond strength is dependent upon the amount of force applied during the application of the tape to the substrate. The sensitive part of pressure sensitive actually refers to how quickly the ultimate bond strength is achieved. The reason you apply pressure at the time of application is to move the polymer chains closer to the substrate so more of them contact it faster.

The need to utilize pressure at the time of application is particularly true when the substrate is not smooth. Skin is a wonderful example. Even discounting wrinkles and hair, skin has peaks and valleys frequently on the order of one to three mils (25-75 microns). Place tape on skin without applying any pressure and the adhesive contacts only the peaks. Depending on the thickness of the adhesive layer and the softness of the adhesive, it could take days for the adhesive to wet the deepest valleys through random motion of the chains. The low points may never be never wetted. A one-mil-thick adhesive coating constrained on a tape backing can't find its way into a low point two mils below the peaks of surrounding features.



In our thought experiment, we now have a substrate well wet-out by adhesive chains and there are lots of interactions holding the adhesive mass in place. The energy required to break all of those interactions is the work of adhesion, but it is only part of the energy needed to separate an adhesive tape from a substrate.

Picture what's happening on the microscopic scale when you peel off a piece of tape. When you pull up on the edge of a tape backing, many things are absorbing the energy you are inputting before the applied force reaches the adhesive/substrate interface and you actually begin to break the bond. All of those energy-absorbing phenomena contribute to the force required to remove the adhesive, increasing the measured peel strength. First, you have to bend the backing. A stiff film backing can contribute a significant percentage to the peel value. Second, the mass of adhesive deforms like a spring until the force is sufficient to overcome the bond strength

When the backing is lifted, the adhesive does not move uniformly as a mass with all segments moving the same distance at the same time. The polymer chains bonded to the tape backing move with it. Through entanglements or crosslinks, these chains pull on others deeper in the adhesive mass. The first chain pulls a second, which pulls a third, etcetera. There are millions of 'first' chains in a layer of PSA. Soon the entire mass is moving.

The thickness of the adhesive layer influences the peel force in several ways. A thicker adhesive coating is equivalent to a longer spring needing to be deformed. It can absorb more energy, reflected in the peel force of the tape, than a thin adhesive. A thicker adhesive coating also aids in the wetting of rough surfaces, as described above. Balancing the 'more is better' paradigm is the fact that thicker adhesive layers have greater cohesive strength challenges and are more likely to split.

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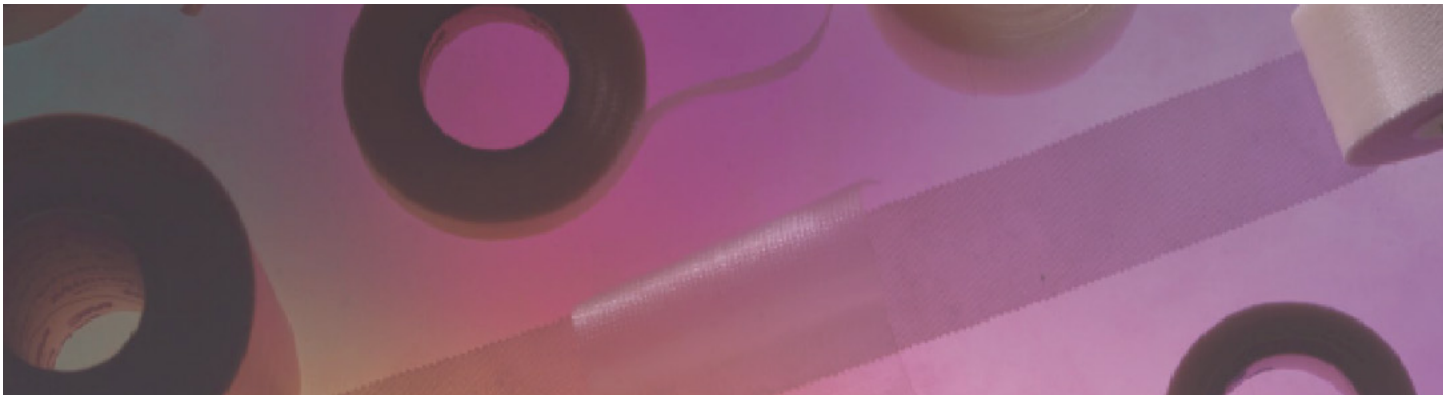
Many properties and performance attributes of a PSA need to be taken into consideration during its development. Obtaining the right balance between conflicting desires, such as adhesive chain mobility for wetting and extensive chain entanglement or crosslinking for cohesive strength can prove a challenge. Fortunately, PSA developers have tools beyond polymer architecture to optimize a PSA for its application.

One such tool is a class of materials called tackifiers. Though they do make adhesives tackier to the touch, in pure form most are solids at room temperature. A second class of additives, plasticizers, make adhesives softer. A key thing to remember about plasticizers and tackifiers: As small molecules, they are mobile. Once adhesive is placed in contact with a plastic surface, it's likely that a fraction of its additives diffuse into the surface and then the bulk of a polymeric substrate. This diffusion is typically inconsequential but can sometimes cause undesirable effects.

One more class of small molecules found in adhesives are the monomers from which the polymer chains are made. The reactions creating the polymers are never perfectly efficient, meaning that adhesives generally contain small amounts of monomer. A key difference between PSAs developed for use in industrial applications and medical adhesives is the level of residual monomer allowed in the final adhesive, with much stricter limits applied to adhesives intended for use on skin.



Much more remains to be said about pressure sensitive adhesives and the polymers at their heart. We hope this brief introduction has helped you understand the components and functionality of PSAs enough to have more meaningful conversations with your adhesive supplier. Discover more at **go.Solventum.com/MedTechOEM**

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