PRESSURE SENSITIVE ADHESIVES

The pressure sensitive adhesive (PSA) is the integral component of any pressure sensitive media or tape. It is often the unseen component of the product, since the middle layer of pressure sensitive media is sandwiched between the facestock and liner. Many pressure sensitive adhesives are clear and therefore not easily detected. On tape products, the adhesive is between the two layers of facestock in a roll and is often used without the applicator noting the existence of the adhesive. As long as the tape sticks during application, no one give the adhesive much notice because it is doing its job. If a pressure sensitive product fails it is usually the adhesive that gets the blame. Most of the time the pressure sensitive adhesive is not the primary reason for an adhesion failure but unfortunately the easiest component to assign blame.

A pressure sensitive adhesive is a material that will hold two surfaces together solely by surface contact. This bond is accelerated by the application of external pressure to the adhesive. PSA's are able to bond a wide variety of materials such as papers, plastics, metals, wood and glass. A PSA is a dry solid that does not require activation by water, solvent, or heat. Pressure sensitive adhesives are permanently tacky at room temperature. Pressure sensitive adhesives can be used as replacement to screws, rivets, nuts and bolts, clips, and any other form of attachment. Ease of application makes PSA's worthy of consideration in many manufacturing processes and makes pressure sensitive media an excellent choice for point of purchase applications and general purpose graphics.

Many chemical materials, (polymers), have been considered for use as a pressure sensitive adhesive over the years. Natural tree gums were one of the first materials to be used as an adhesive. While certain tree saps have some initial pressure sensitive properties they usually oxidize quickly and loose tackiness with any exterior exposure. Over time, synthetic polymers have been identified to possess the properties required to perform as a PSA. Some of the more common pressure sensitive polymers are:

ACRYLIC

Acrylic pressure sensitive polymers are widely used in the manufacture of a PSA's. Typical acrylic monomers such as acrylic acid, methyl methacrylate, 2-ethyhexyl acrylate, butyl acrylate, and other monomers when polymerized will form permanently tacky acrylic polymers. Acrylic monomers are polymerized in a reactor under heat, pressure, specific time and catalysts to produce an acrylic pressure sensitive polymer. The advantages acrylic PSA's offer are: excellent clarity, good color stability, better resistance to oxidization, higher resistance to heat and ultra violet radiation. Acrylics bond well to polar surfaces such as metals, glass, polyester and polycarbonate plastic films. A disadvantage of an acrylic PSA is low bond to low surface energy surfaces such as polyethylene or polypropylene. Overall an acrylic PSA has good general purpose physical properties, a balance of peel and shear properties that enable them to be used in long-term exterior applications. The unlimited variability in formulation and choice of monomers make an acrylic polymer ideal for most pressure sensitive adhesive applications.

RUBBER BASED

Over the history of pressure sensitive adhesives, rubber based pressure sensitive adhesives are recognized as the first commercially available to the industry. They are derived from common raw materials, easy to produce and offer wide range of formulation possibilities. A rubber based polymer does not have pressure sensitive properties at room temperature. It has to be formulated with tackifying resins, oils, plasticizers, antioxidants and possibly pigments to produce a functional pressure sensitive adhesive. Rubber based PSA's provide high adhesion to a variety of substrates and face stocks including low energy plastics such as polyethylene and polypropylene. Historically rubber based PSA's offer the lowest production costs of all pressure sensitive adhesives. Limiting properties of rubber based PSA's are poor chemical resistance, degradation at temperatures over 150 F, and poor UV resistance. These factors limit the useful life of a rubber based PSA's for exterior applications. In addition, they are susceptible to oxidation over time, which will cause them to darken, loose tack, and become brittle. When matched with or laminated to a plasticized vinyl film, plasticizer from the vinyl can migrate into the adhesive turning it gummy and losing any shear or holding power of the adhesive. It must be tested thoroughly when formulating a pressure sensitive product with flexible vinyl and a rubber based PSA.

Natural Rubber Resins

Natural rubber is derived from a variety of trees as a white milky latex. The primary tree species that produce rubber latex is Para rubber tree (Hevea brasiliensis). Latex can also be known as Congo rubber from vines in the genus Landolphia. Dandelion sap also contains a low level of rubber latex. During World War II Germany investigated dandelion sap as a source of rubber latex without success. Latex can go through a number of processes to coagulate the rubber polymer. The primary natural rubber polymer is cis-1,4-polyisoprene.

Synthetic Rubber Resins

While Para rubber trees are indigenous to South America, natural rubber is not commercially cultivated because of South American leaf blight. In the 1870's seedlings were sent to India, Sri Lanka, Thailand, Indonesia, Singapore and Malaysia to establish plantations. This area of the world became the leading supplier of rubber latex. With the onset of World War II this supply vanished forcing the USA to find alternate sources of rubber polymers, primarily to supply the war effort. Scientists started looking to synthetically produce rubber polymers in the early 1900's as a replacement for natural rubber in pneumatic bicycle tires. As rubber demand continued to grow the cost of natural rubber increased further pushing demand for synthetic rubber. In 1940 a B.F. Goodrich scientist, Waldo Semon, developed a cost effective synthetic rubber named Ameripol. The U.S Government also sponsored a major development to improve synthetic rubber that was successful in producing a styrene butadiene copolymer used to manufacture war material that was derived from petroleum based monomers.

In today's economy about two thirds of the total rubber supply is provided by synthetic polymers. Styrene-butadiene rubber, (SBR) is widely used to produce PSA's. SBR has higher temperature resistance than natural rubber but lower strength, resilience and poor low temperature properties when compared to natural rubber. To optimize PSA properties, SBR resins are blended with natural rubber to optimize adhesive performance properties.

The other family of synthetic rubber resins used in PSA formulations are Styrenic Block Copolymers, (SBC). These resins have styrenic endblocks with mid blocks of either polyisoprene, (SIS) or polybutadiene, (SBS). Like natural rubber these resins have little tack at room temperature and must be formulated to produce a PSA. SBC's offer wide formulation latitude between tack and shear properties to meet just about any requirement. They have similar advantages and disadvantages as natural rubber resins.

SILICONE

Silicone polymers are used for extremely high performance PSA's. Silicone PSA's offer both high temperature resistance (up to 500ºF) along with the ability to bond at extremely low temperatures (-100ºF). Silicone PSA's have excellent chemical resistance along with the ability to bond to low energy substrates such as silicone and silicone release liners. Silicone PSA's can be difficult to coat and process in that some require curing temperature greater than 300ºF, requiring high temperature resistant substrates. Silicone polymers are also the most expensive PSA resins by far limiting their applicability to only the highest performance tapes and media where rubber based and acrylic resins cannot meet the performance requirements.

TYPES OF PRESSURE SENSITIVE ADHESIVES

Another property associated with a pressure sensitive adhesive is the type of adhesive. In order to obtain a smooth and consistent thickness; a PSA is coated from a liquid or an extremely low viscosity and converted to a solid. The common commercially available types of PSA's are:

SOLVENT

When a PSA is solvent borne it means the adhesive resins and components are dissolved in solvents such as ethyl acetate, toluene, isopropyl alcohol, heptane, MEK and others to form a liquid. This liquid is then coated and the solvent evaporated by heat to form a smooth consistent thickness layer of PSA. Acrylic, rubber based, and silicone resins can all be manufactured as solvent PSA's. Solvent PSA's are easily formulated and can be additionally crossed linked to meet just about any application requirement. Solvent based acrylics can be formulated for excellent chemical and heat resistance along with ultra violet light resistance that enables it to be considered for long-term exterior applications. Solvent PSA's have a higher adhesive manufacturing cost and require special processing steps to control solvent emissions that further add to manufacturing costs. However, solvent borne PSA's can be considered high performance adhesives.

EMULSION OR WATER BASED

In an emulsion pressure sensitive adhesive, the resin and additives are dispersed in water to form the liquid adhesive. While acrylics are the most common emulsion PSA's, rubber and silicone resins can also be produced in an emulsion version. Again the adhesive is coated in liquid form and heat is applied to evaporate the water leaving the solid adhesive. While emulsion PSA's continue to evolve and performance improves, the use of additives to manufacture the adhesive can effect performance. Wetting agents, surfactants, thickeners and defoamers all remain in the adhesive in the dried state. Wetting agents and surfactants are water sensitive and can scavenge moisture back into the PSA acting as a plasticizer and reducing the holding power of the adhesive. This can be temporary depending of environmental conditions but repeated cycles of exposure can reduce long–term performance. Manufacturing costs of emulsion adhesives are usually lower than solvent borne adhesives and do not require the capital outlay or ongoing costs of emission control devices. Overall emulsion PSA are very competitive for removable, short term and general purpose applications.

HOT MELT

A hot melt pressure sensitive adhesive is a 100% solid adhesive that becomes low in viscosity and takes on a liquid like flow when heated. It is then coated while in the low viscosity state and rapidly cooled before laminating to a heat sensitive stock. Typical thermoplastic elastomers used as hot melt PSA's are the styrenic block copolymers, (SBC). Being a rubber based resin hot melt adhesives have generally poor high temperature resistance given they will return to the flowable condition as temperature increases. Hot melt adhesives are generally used for interior applications where they are not exposed to high temperatures or UV radiation.

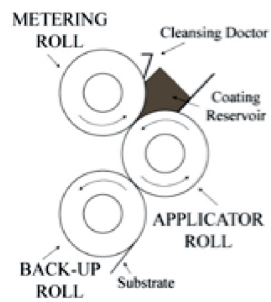
ENERGY CURABLE

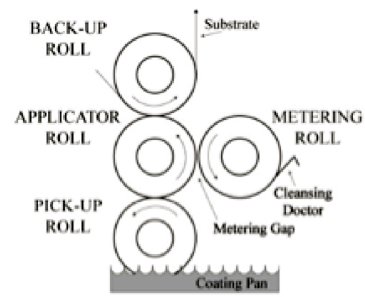
Another version of 100% solids pressure sensitive adhesive is an energy curable PSA. The most common type of energy curable PSA's use ultra violet radiation curing, (UV curable). There was some early work using electron beam curing for a PSA but the capital investment is large with limited adhesive formulation variability. These factors have limited growth. UV curable PSAs' are a complex mixture of oligomers, monomers, photoinitiators and additives. This gives a wide range of PSA formulations available to meet any application. In addition, processing conditions can effect the cross linked density of the PSA thereby changing the physical properties of a specific UV curable formulation. Being a thermoset adhesive after curing, a UV curable PSA offers excellent high temperature and chemical resistance, excellent holding power and moisture resistance. Most UV curable PSA's are 100% solids and do not require emission control equipment.

METHODS OF APPLICATION

There are various ways to apply a pressure sensitive adhesive to the substrate to form a tape or digital media. Some application techniques are common with a certain adhesive type but generally any method of adhesive application can be considered for any type of pressure sensitive adhesive.

REVERSE ROLL





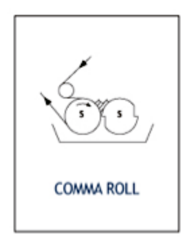
This technique is a precise alignment of three smooth, usually chromed, rolls that have a gap between the applicator roll and the metering roll. The substrate to be coated wraps the bottom backing roll tightly and rotates in the direction the substrate travels through the coater. There is a slight gap between the metering and applicator rolls that the adhesive flows through. The applicator roll rotates against the direction of substrate travel giving the procedure its name, reverse roll. Reverse rotation gives the adhesive a smooth consistent coating thickness on the substrate. Gap and speed of rotation are the control factors that determine adhesive thickness. This procedure is widely used for solvent and to some extent water based adhesives. There are other variations of reverse roll coating as shown by the diagram for a pan fed system. This is a very versatile adhesive application procedure and can be adapted to just about any adhesive formulation.

KNIFE OVER ROLL

This technique is similar to reverse roll with the metering roll being replaced by a rigid smoothly ground blade. The coated substrate is tight to the bottom roll with a gap between the substrate and blade to meter the thickness of the adhesive. Knife over roll coating is simple, easy to adjust coating thickness and easy to clean allowing for fairly quick changes. It is ideal for higher viscosity coatings such as solvent borne acrylics and rubber based PSA's.

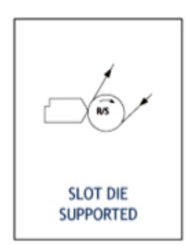
COMMA COATER

A comma coater is comparable to knife over roll coating but the knife is replaced with a rod knife. This is a rod that has a notch in it. Coating is metered on the substrate by a gap between the backing roll and the rod knife. There are versions of comma coaters where the coating is applied to a smooth roll then transferred to the substrate. Comma coaters produce very smooth coatings of adhesive that can compensate for irregularities in the coated substrate. Comma coaters are ideal for high viscosity adhesives and should be considered when applying solvent acrylic and rubber based PSA's.



SLOT DIE

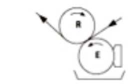
In slot die coating, adhesive is pumped into the die manifold by a positive force pump forming in a pulse free pool of adhesive that results in smooth uniform coating thickness and surface. Adhesive then is distributed from the die manifold through the slot to the substrate. There is a gap between the die and substrate that meters the thickness of the adhesive on the substrate. Slot die coating can handle a wide range of adhesive viscosities at a wide range of thicknesses. Slot die coaters offer precise control of



adhesive thickness both across the width and length of the substrate. Slot die coating is ideal for long run production that require consistent adhesive thickness.

GRAVURE

Gravure coating involves etching a pattern into a smooth roll that contains the adhesive. As the roll rotates, the coated substrate comes in contact with the gravure roll and the coating is transferred from the gravure cylinder to the substrate. There are various etching patterns depending on the viscosity and the desired dry thickness of the adhesive. The most common etch pattern for adhesive coating is a tri helical pattern with the depth of engraving depending on the final dry thickness and percent solids of the adhesive. Gravure coating is ideal for lower viscosity adhesives making it a common application method for acrylic emulsion PSA's.



FORWARD GRAVURE with APPLICATOR

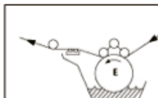
Direct, (forward), or reverse gravure denotes the direction of rotation of the gravure cylinder relative to the movement of the coated substrate. In direct gravure, rotation of the gravure cylinder is in the same direction as the coated substrate. In reverse gravure coating, the gravure cylinder rotates against the direction of substrate movement.

REVERSE GRAVURE PAN

Offset gravure signifies there is at least one intermediate roll between the gravure roll and the coated substrate. Adhesive is transferred from the gravure roll to the intermediate roll to the coated substrate. Advantages of offset gravure are the intermediate roll allows the adhesive to flow out before application to the substrate giving a smoother adhesive coating and it can allow for the application of thinner thickness of coating. Disadvantages are more complexity can induce more variability into the coating process and longer clean up and change overs.

WIRE ROD (MAYER ROD)

Wire rod coating involves using a grooved rod to meter the adhesive on a substrate. Early versions involved winding different gauge wires around a steel rod with the adhesive flowing through the gaps formed by the voids between each wrap of wire. Later technology evolved to grinding the groves directly in a steel rod then chrome plating for smoothness. In the wire rod coating process, adhesive is flooded on the coated substrate and a wire rod wipes off the excess leaving a uniform thickness of adhesive. Wire rod coating is ideal for low viscosity adhesives and offers the advantage of quick and easy thickness adjustment by changing the wire rod. The first reference to wire rod coating are from 1800's in Germany and this process is still widely used today.



METERING ROD (SINGLE OR DUAL)

Pressure sensitive adhesives are complex polymers that can be formulated from a wide variety of raw materials to meet any specialized requirement. The various coating methods can accommodate any viscosity and solids variability associated with a specific PSA formulation. Therefore, it is possible to develop then produce a PSA tape or media by combining adhesive formulation with the optimal production process. General Formulations offers a vast selection of PSA formulations that can be combined with different substrates to meet your requirements. Consult with your General Formulations Customer Service Representative for assistance in determining the correct PSA product to meet your needs. Your representative can be reached by phone at 800-253-3664 or through the website: www.generalformulations.com. Your customer service representative is available under Contact Us/Customer Service Team.

ACKNOWLEDGEMENT

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