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PSA Assembly Guidelines for Single-Sided and Double-Sided Flexible Printed Circuits

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A standard developed by IPC

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Developed by the Pressure Sensitive Adhesive Task Group (D-13b)
of the Flexible Circuits Committee of IPC

Users of this standard are encouraged to participate in the
development of future revisions.

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Acknowledgment

Any Standard involving a complex technology draws material from a vast number of sources. While the principal members of the Pressure Sensitive Adhesive Task Group (D-13b) of the Flexible Circuits Committee are shown below, it is not possible to include all of those who assisted in the evolution of this standard. To each of them, the members of the IPC extend their gratitude.

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PSA Assembly Guidelines for Single-Sided and Double-Sided Flexible Printed Circuits

1.0 INTRODUCTION

This document is intended to provide the designer/user with information related to the use of pressure sensitive adhesives (PSA's) for assembly of flexible printed circuits/wiring (FPC/FPW) and membrane switches. This guide provides information on adhesive types available and processes suggested for their proper use, highlights strengths, weaknesses, or limitations; how to start implementation and where to find additional information.

1.1 Scope This document provides guidelines for the use of PSA's in single or double sided flexible printed circuits (see figures 3, 4, 5, 6, 7, 8, 9), membrane switches (see figures 10, 11, 12, 13) and component attachments (see figures 2, 14). In addition, the guideline describes the type of materials and processes that may be used to accomplish proper assemblies.

1.2 Purpose This document is intended as a **guide** to the user by seeking answers to questions related to accepted, effective methods for the use of PSA's in FPC assemblies. **The methods described herein are not standards.** PSA technology is continuously evolving such that applications and requirements may vary beyond the scope of this publication.

1.3 Classification of PSA's

1.3.1 Physical Characteristics

- A. Unsupported transfer adhesive on release liner(s).
- B. Adhesive coated on one side of a film, foil, foam, or paper carrier.
- C. Adhesive coated on two sides of a film, foil, foam, or paper carrier.
- D. Liquid (UV curable) PSA that is screen printable.

1.3.2 Adhesive Types Pressure Sensitive Adhesive (PSA) is a term used to designate a distinct category of adhesives and adhesive tapes which in their dry (solvent-free) form are permanently tacky at room temperature and adhere to a variety of dissimilar surfaces upon contact with light pressure from a finger, hand, roller or other device.

Pressure Sensitive Adhesives can be made from a variety of elastomers (rubber-like materials) compounded with additional ingredients to enhance performance, reduce the effect of environmental degradation and provide for appearance. The largest volume of PSA's are made from natural and/or synthetic rubber, thermoplastic block copolymers, acrylic and silicone polymers.

Many of the rubber and thermoplastic elastomers are formulated with low molecular weight additives called tackifiers to increase the tackiness and peel adhesion of the base rubber (elastomer). Tackifiers for non-silicone elastomers are obtained from wood rosin, terpene resins and also from certain petrochemical products. Terpene resins and fully hydrogenated synthetic tackifying resins provide for superior environmental aging of the PSA. Certain acrylate and silicone elastomers are inherently tacky; a variety of acrylic PSA's may be produced by changing the acrylic monomer composition. Silicone tackifiers are made from another silicone polymer which has a three dimensional structure.

Other ingredients called plasticizers can be added to the base rubbers to soften the PSA and improve tack performance. Low molecular weight additives contained in a PSA have the potential to react with the base elastomer resulting in reduced adhesive performance and transfer of chemical residue to the mating surface. Diffusion of additives out of the PSA can produce a "drying out" effect or loss of tack over time.

Antioxidants are added to non-silicone and non-acrylic PSA formulations to protect against oxidation of the elastomer. Oxygen chemically attacks the PSA and lowers the cohesive strength of the adhesive by breaking the polymer chains. Several antioxidants are added to protect PSA's, (other than acrylics and silicones), from degradation due to UV light, heat and the effects of oxygen. A color change may occur at the bond interface with certain antioxidants. Inert fillers can be added to reduce cost, increase strength and alter the appearance of the PSA. Metal or ceramic fillers may be added to give the PSA the added functionality of electrical or thermal conductivity or both.

Some PSA's are crosslinked to provide improved holding power and environmental aging properties. Increased crosslinking may result in lower tack and peel performance of a PSA.

PSA's are usually characterized as permanent, repositionable or fully removable. Permanent PSA's adhere aggressively to the substrate and are not easily removed once contact is made with the mating surface. Repositionable PSA's allow for removal and replacement within a defined time span after which they become permanent. Fully removable PSA's allow repeated application and removal without loss of adhesive integrity. Some removable PSA's do leave an invisible residue on the substrate, usually a low molecular weight additive or residual polymer. This residue may have an effect on subsequent processing of this surface.



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GENERIC TYPES OF PSA'S Typical properties are shown in Table 1.

Table 1 Typical Properties of Generic PSA's

	Silicone Based	Acrylic Based	Rubber Based	UV Based
180° Peel Adhesion [N/M]	10 to 120	10 to 300	16 to 100	16–96
Service Temperature °C Range	–73 to 260	–40 to 177	4 to 80	–17 to 93
Short Term Thermal Exposure (solder reflow 10 sec 260°C)	Yes	Yes	No	Yes
CREEP RESISTANCE Holding Power at Room Temperature 23°C	+	+	+	+
Holding Power at Elevated Temperature (93°–149°C)	+	+	–	0
Adhesion to Low Energy Surfaces	+	–	+	+
Ultraviolet Light Resistance	+	+	–	–
Oxidation Resistance	+	+	–	0
Flame Retardancy	+	0	0	0
Organic Solvent Resistance	0	0	–	–
Water Resistance	+	+	+	+
Alcohol Resistance	+	+	–	0
Relative Cost	–	+	+	+

+ = strength - = weakness 0 = Formulation dependent

A. Rubber Resin Based PSA's Natural rubber and natural rubber/synthetic rubber blends modified with tackifiers and antioxidant represent the oldest and probably the largest family of PSA's. This family of PSA's has good adhesion to a variety of surfaces and can be formulated to have good tack and shear properties. Typical formulations of rubber based PSA's have a service temperature limited to a maximum of 82°C, susceptibility to oxidative solvents, poor UV resistance and degradation due to thermal and oxidative environments.

B. Block Copolymer Based PSA's Block copolymer PSA's are formulated from thermoplastic rubbers such as styrene butadiene or styrene polyisoprene copolymers plus tackifiers and plasticizers to develop the required tack. These PSA's tend to be tough and firm with aggressive adhesion. However, since these elastomers are thermoplastic, their use temperature tends to be limited to conditions below their glass transition temperature (T_g) of the thermoplastic phase. Typical range for maximum adhesion and holding power is 82°C to 93°C.

C. Acrylate Based PSA's Acrylate based PSA's are formulated from acrylic polymers whose properties can be tailored from various combinations of acrylic monomers. Acrylic PSA's can be coated from either a solvent system or water based emulsions. Acrylic PSA's produced from emulsions tend to have an affinity for moisture and typically are not used in high humidity environments i.e., greater than 70% relative humidity.

If used in high humidity environments, acrylic PSA's produced from emulsions will either totally fail from adhesive re-emulsification or will suffer a serious degradation of bond strength. It is important that the designer ask the PSA vendor whether their materials is coated from a "solvent" solution or from an "emulsion." Solvent acrylate PSA's are strongly recommended for FPC assembly applications.

Acrylate based PSA's are used in applications where environmental resistance, high ultimate peel strength, high holding power, and/or high temperature resistance are required. For instance, assemblies bonded with acrylic PSA's can withstand solder reflow temperatures. Acrylic PSA's can be formulated to have:

1. High initial and permanent bond strengths.
2. Initial repositionability building to a high, permanent bond over time (i.e., 24 to 72 hours).
3. Or low initial and long term bonds resulting in clean removability over extended time periods.

Acrylate based PSA's are widely used for many industrial OEM applications because of their excellent balance of properties, aging characteristics and versatility. A typical application is the bonding of stiffeners to flexible circuitry assemblies.

D. Silicone Based PSA's Silicone PSA's provide excellent temperature performance compared to rubber or acrylic PSA's, and exhibit good adhesion properties at both high and low temperatures. Silicone PSA's also have good adhesion to low surface energy substrates such as polyethylene or fluorocarbon. Silicone PSA's are typically produced from a solvent solution and possess good resistance

to thermal and oxidative degradation. Some removable silicone PSA's may leave a residue that could affect subsequent adhesion. Silicone PSA's offer excellent conformability to uneven surfaces, high temperature performance, but tend to have lower peel strengths than acrylics and tend to be more expensive than other PSA's. Silicone PSA's are inherently flame retardant and thus do not require chemical additives that may cause ionic degradation resulting in changes of electrical properties of the finished circuitry.

E. UV Cured Screen Printable PSA UV cured pressure sensitive adhesives are typically 100% non-volatile liquids prepared by polymerization of acrylate polymers and monomers. In addition, UV curable PSA formulations requires a photo initiator that dissociates rapidly in the presence of UV light or an electron beam (EB) generating chemical free radicals which initiate the crosslinking of the adhesive. The curing reaction is completed in seconds. UV cured PSA's exhibit similar properties to thermally cured PSA's, i.e., improved shear and creep resistance.

UV curable PSA's are applied by the same equipment used for solvent and water based PSA's including screen printers. The ability to selectively screen print UV curable PSA's is attractive because the adhesive can be applied where the adhesive is needed thus minimizing waste. In addition, UV curing produces a minimum amount of heat allowing UV curable PSA's to be applied to temperature sensitive substrates.

Screenable UV (liquid) pressure sensitive adhesives are 100% non-volatile materials and typically have little or no shrinkage below 70°C. At temperatures greater than 70°C some shrinkage may occur in the adhesive coating, but typically less than 2%. Because the coating conforms to the substrate material upon which it is applied, shrinkage of the substrate material would be the governing factor.

UV curable PSA's can be formulated to achieve a wide range of peel, shear and tack properties. However, UV curable PSA's typically have lower temperature resistance than acrylic or silicone PSA's.

Performance of a UV cured PSA is dependent upon achieving a properly cured condition. Most UV cured PSA's require a specific energy level (Joules/cm²) for a given adhesive thickness to achieve optimal performance properties.

The variability of UV curing equipment requires that the system be carefully calibrated to ensure that the adhesive will be properly cured. Typically, UV curing systems are calibrated by performing a "cure ladder" study. A cure ladder study consists of running samples at various UV light intensities and dwell times until the UV cured PSA achieves the desired shear and peel properties. If several UV curing devices will be used, it is recommended that a cure ladder study be conducted on each device. In addition

to the UV light source, the final cure state can be affected by cooling techniques, use of focused or diffused light and changing from IR excited to microwave exciting sources.

1.3.3 PSA Adhesive Classifications

1.3.3.1 Permanent Designed for maximum bond strength. Failure mode for many permanent PSA's is substrate deformation and/or cohesive failure.

Permanent PSA's are typically used for bonding, mounting, laminating or other assembly applications.

1.3.3.2 Repositionable Permanent PSA's can be formulated to have high initial bond strength or they can be formulated to be initially repositionable, building to a permanent bond over a 24 to 72 hour period. See Figure 1.

This class of PSA's should be considered as permanent PSA's with the added feature of the ability to remove/reposition within a limited time interval. Typically, repositionable PSA's require more time to achieve maximum adhesion and may be better suited for hand assembly applications. Once full adhesion is achieved removal may cause substrate deformation or cohesive failure.

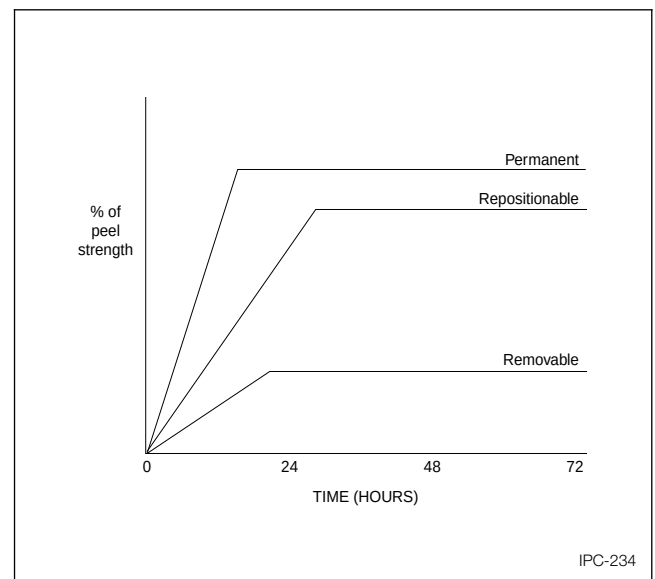


Figure 1 Graph of PSA Bond Strength

1.3.3.3 Removable This family of PSA's is designed to be cleanly stripped off leaving no adhesive residue even after extended time periods of bonding. The ultimate bond strength of a removable PSA is much lower than that of a permanent PSA.

Removable PSA's are typically used for masking tapes and removable label applications.

1.3.3.4 Ultimate Bond Strength Because of the viscoelastic properties, PSA's do not achieve their maximum performance (i.e., holding power, moisture resistance, heat

resistance, etc.) until their ultimate bond strength is reached. This occurs when the adhesive has wet out 100% of the surfaces to be bonded via cold flow. Maximum or ultimate bond strength is usually obtained 24 to 72 hours after the initial bond is made; this will vary depending upon adhesive formulations and application or lamination methods.

2.0 REFERENCE DOCUMENTS

2.1 N.A.S.A. Goddard Space Flight Center Publication 1124

Outgassing Data for Selecting Spacecraft Materials

2.2 ASTM E-595

Standard test method for total mass and collected volatile condensable materials from outgassing in a vacuum environment.

3.0 TERMS AND DEFINITIONS (specific to pressure sensitive adhesives)

3.1 Acrylic – A family of synthetic acrylate ester polymers with excellent aging characteristics that can be used as adhesive coating or saturant, depending upon composition.

3.2 Adhesion – The bond produced by contact between a pressure-sensitive adhesive and a surface.

3.3 Adhesive Transfer – The transfer of adhesive from its normal position on the tape to the surface to which the tape was attached, either during unwind or removal.

3.4 Cohesion – (Cohesive strength, internal bond) The ability of the adhesive to resist splitting. Good cohesion is necessary for clean removal.

3.5 Cold Flow – The tendency of some Pressure Sensitive Adhesives to act like a heavy viscous liquid and exhibit a limited amount of flow over a period of hours or days at room temperature. Increases in adhesion can take place as the result of improved wetting of the substrate surface.

3.6 Dynamic Shear – A test in which shear force is increased until the bond fails. The results are reported in units of force per unit of area. The order of magnitude of dynamic shear value for a PSA is 690 kPa as compared to the dynamic shear for a thermoset adhesive of 6900 kPa.

3.7 Electrolytic Corrosion Factor – A measure of the tape's corrosive effect on a copper conductor. This is particularly important in selection of tapes for use as electrical insulation.

3.8 Fish Eyes – Relatively small deformations (pock marks) in the adhesive coating.

3.9 Flame Resistance – The ability of a tape to withstand exposure to flame. Fire-proof materials will not burn even when exposed to flame. Flame proof (fire-retardant, self-extinguishing) materials will burn when exposed to flame, but will not continue to burn after the flame is removed.

3.10 Heat Resistance – The ability of a tape to withstand exposure to specific temperatures after application to a surface. Clean removal after exposure may or may not be important depending on the intended function of the tape and the type of adhesion.

3.11 Holding Power – (Creep Resistance) – The ability of a tape to resist the static forces (shear adhesion) applied in the same plane as the backing. Usually expressed in time required for a given weight to cause a given amount of tape to come loose from a vertical panel.

3.12 Migration – The movement over a long period of time, of an ingredient from one component to another when the two are in surface contact. This may occur between tape components or between a tape and the surface to which it is applied. Some plastic films and foams contain plasticizers which are apt to migrate into the tape adhesive, causing the adhesive to soften.

3.13 Oozing – A “squeezing out” of the adhesive from under the backing. Soft and tacky PSA's plus higher coating thickness increase the tendency to ooze. PSA's can be formulated to be resistant to oozing.

3.14 Peel Adhesion – The force required to break the bond between a tape and the surface to which it is applied. Usually measured by peeling back the tape at 180 degrees or sometimes at 90 degrees in the case of certain backings, and at a standard rate and condition, and expressed in ounces or pounds per inch width.

3.15 Quick Stick – (Tack, Finger Tack, Initial Adhesion, Wet Grab) The property of a pressure sensitive adhesive which allows it to adhere instantly to a surface under very light pressure. It is determined by the ability of the adhesive to quickly wet the surface contacted.

3.16 Release Liner – A web or sheet of material covering the adhesive side of a tape. It is removed prior to application. Most frequently found on double-coated tapes and label stocks.

3.17 Silicone – A polymer system containing silicone which can be a very effective release coating, or a pressure sensitive adhesive capable of functioning effectively at extreme temperatures.



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