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Pressure Sensitive Adhesive (PSA) Assembly Guidelines for Flexible, Rigid or Rigid-Flex Printed Boards

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Developed by the Flexible Circuits Base Materials Subcommittee (D-13)
of the Flexible Circuits Committee (D-10) of IPC

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

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Pressure Sensitive Adhesive (PSA) Assembly Guidelines for Flexible, Rigid or Rigid-Flex Printed Boards

1 INTRODUCTION

This document is intended to provide the designer/user with information related to the use of pressure sensitive adhesives (PSAs) for assembly of flexible printed boards 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 PSAs in single or double sided flexible printed circuits (see Figures A2 through A8), membrane switches (see Figures A9 through A12) and component attachments (see Figures A1 and A13). 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 PSAs in FPC assemblies. **The methods described herein are not specifications.** PSA technology is continuously evolving such that applications and requirements may vary beyond the scope of this publication.

1.3 Classification of PSAs

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

PSAs are usually characterized as permanent, repositionable or fully removable. Permanent PSAs adhere aggressively to the substrate and are not easily removed once contact is made with the mating surface. Repositionable PSAs allow for removal and replacement within a defined time span after which they become permanent. Fully removable PSAs allow repeated application and removal without loss of adhesive integrity. Some removable PSAs 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.

GENERIC TYPES OF PSAs Typical properties are shown in Table 1-1.

Table 1-1 Typical Properties of Generic PSAs

	Silicone Based	Acrylic Based	Rubber Based	UV Based
180° Peel Adhesion N/25mm [lb/in]	5.6 to 16.9 N/25mm [1.28 to 3.86 lb/in]	22.6 to 50.8 N/25mm [5.16 to 11.60 lb/in]	16.9 to 33.9 N/25mm [3.86 to 7.74 lb/in]	16.9 to 28.2 N/25mm [3.86 to 6.44 lb/in]
Typical Supplier Stated Service Temperature Range °C [°F]	-73 °C to 260 °C [-99 °F to 500 °F]	-40 °C to 177 °C [-40 °F to 351 °F]	4 °C to 80 °C [39 °F to 176 °F]	-17 °C to 93 °C [1 °F to 199 °F]
Short Term Thermal Exposure (solder reflow: 10 sec/260 °C [500 °F])	Yes	Yes	No	Yes
Creep Resistance Holding Power at Room Temperature 23 °C [73 °F]*	4	4	4	4
Holding Power at Elevated Temperature of 93 °C to 149 °C [199 °F to 300 °F]*	3	3	1	FD
Adhesion to Low Energy Surfaces*	3	2	3	3
Ultraviolet Light Resistance*	5	4	2	2
Oxidation Resistance*	5	4	1	FD
Flame Retardancy*	5	FD	FD	FD
Organic Solvent Resistance*	FD	FD	2	2
Water Resistance*	5	4	5	4
Alcohol Resistance*	5	4	2	FD
Electrical Conductivity	See Paragraph 4.11.3			
Thermal Conductivity	See Paragraph 4.13			
Outgassing	See Paragraph 4.12			

*5: strongest, 1: weakest, FD: Formulation Dependent

A. Rubber Resin Based PSAs Natural rubber and natural rubber/synthetic rubber blends modified with tackifiers and anti-oxidant represent the oldest and probably the largest family of PSAs. This family of PSAs has good adhesion to a variety of surfaces and can be formulated to have good tack and shear properties. Typical formulations of rubber based PSAs 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 PSAs Block copolymer PSAs are formulated from thermoplastic rubbers such as styrene butadiene or styrene polyisoprene copolymers plus tackifiers and plasticizers to develop the required tack. These PSAs 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 PSAs Acrylate based PSAs are formulated from acrylic polymers whose properties can be tailored from various combinations of acrylic monomers. Acrylic PSAs can be coated from either a solvent system or water based emulsions. Acrylic PSAs 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 PSAs 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 PSAs are strongly recommended for FPC assembly applications.

Acrylate based PSAs 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 PSAs can withstand solder reflow temperatures. Acrylic PSAs can be formulated to have:

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

Acrylate based PSAs 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 PSAs Silicone PSAs provide excellent temperature performance compared to rubber or acrylic PSAs, and exhibit good adhesion properties at both high and low temperatures. Silicone PSAs also have good adhesion to low surface energy substrates such as polyethylene or fluorocarbon. Silicone PSAs are typically produced from a solvent solution and possess good resistance to thermal and oxidative degradation. Some removable silicone PSAs may leave a residue that could affect subsequent adhesion. Silicone PSAs 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 PSAs. Silicone PSAs 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 PSAs exhibit similar properties to thermally cured PSAs, i.e., improved shear and creep resistance.

UV curable PSAs are applied by the same equipment used for solvent and water based PSAs including screen printers. The ability to selectively screen print UV curable PSAs 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 PSAs 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 PSAs can be formulated to achieve a wide range of peel, shear and tack properties. However, UV curable PSAs typically have lower temperature resistance than acrylic or silicone PSAs.

Performance of a UV cured PSA is dependent upon achieving a properly cured condition. Most UV cured PSAs 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 PSAs is substrate deformation and/or cohesive failure.

Permanent PSAs are typically used for bonding, mounting, laminating or other assembly applications.