



ASSOCIATION CONNECTING
ELECTRONICS INDUSTRIES

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Guidelines for Electrically Conductive Surface Mount Adhesives

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A standard developed by IPC

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Developed by the SMT Mounting Adhesives Task Group (5-24d) of the
Assembly and Joining Materials Subcommittee (5-24) of IPC

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

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Table of Contents

1.0 SCOPE	1	6.4.1 Assembly With Isotropic Thermoset Pastes	9
1.1 Introduction	1	6.4.2 Assembly With Isotropic Thermoplastic Pastes	10
2.0 APPLICABLE DOCUMENTS	1	6.4.3 Assembly With Anisotropic Pastes	10
2.1 IPC	1	6.4.4 Assembly With Anisotropic Films	10
3.0 BASIC TYPES AND FEATURES	1	6.5 Hardening the Adhesive	10
3.1 Benefits and Limitations of Conductive Adhesives	1	6.5.1 Thermosets	10
3.1.1 Types of Conductive Adhesives	1	6.5.2 Thermoplastics	10
3.1.2 Comparison of Metallurgical Solder and Conductive Adhesives	2	6.6 Special Operations	10
3.1.3 Key Differences Between Isotropic Conductive Adhesives and Solder	2	7.0 REPAIR	11
3.1.3.1 Mechanical-Electrical Independence	2	7.1 Thermoplastic Systems	11
3.1.3.2 Volume Differences	3	7.2 Thermosets	11
3.1.3.3 The Joining Process	4	7.3 Anisotropics	11
3.1.3.4 Cleaning	5	8.0 PERFORMANCE	11
3.1.3.5 Surface Tension	5	8.1 Mechanical	11
4.0 MATERIALS	5	8.1.1 Bond Strength	11
4.1 Types of Polymers	5	8.1.2 Thermomechanical Strength	11
4.1.1 Thermoplastics	5	8.2 Electrical	11
4.1.2 Thermosets	6	8.2.1 Volume Resistivity	11
4.2 Fillers	6	8.2.2 Junction Resistance	12
5.0 BASIC TYPES OF CONDUCTIVE ADHESIVES	6	8.2.3 Junction Stability	12
5.1 Intrinsically Conductive Polymers (ICP)	6	8.3 Chemical	12
5.2 Isotropically Conductive Adhesives	7	8.4 Compatibility	12
5.3 Anisotropic Conductive Adhesives	7	9.0 TESTING DIFFERENCES COMPARED TO SOLDER	12
5.3.1 Random Conductor Type	7	9.1 Printability/Applicability	12
5.3.2 Patterned Conductor Type	7	9.2 Hardening/Curing/Polymerization	12
5.4 Nonconductive Adhesives Used for Electrical Connections	7	9.3 Mechanical	12
6.0 APPLICATION AND ASSEMBLY PROCESS	7	9.4 Electrical	12
6.1 Applying Isotropic Pastes	7	9.5 Inspection	12
6.1.1 Screen Printing	7		
6.1.2 Stenciling	8		
6.1.3 Pad Printing	8		
6.1.4 Dispensing	8		
6.1.4.1 Needle Dispensing	8		
6.1.4.2 Manifolds	9		
6.1.4.3 Fluid-Jetting	9		
6.1.4.4 Pin Transfer	9		
6.2 Applying Anisotropic Pastes	9		
6.3 Applying Anisotropic Films	9		
6.4 Component Placement	9		

Figures

Figure 3-1 Metallurgic solder (shown only as tin for simplicity)	3
Figure 3-2 Electrical paths in isotropic conductive adhesive	3
Figure 3-3 Isotropic conductive adhesive joint	4
Figure 3-4 Anisotropic conductive adhesives junctions	4
Figure 3-5 Result of evaluating conductive adhesive using a screen designed for solder paste	5

Guidelines for Electrically Conductive Surface Mount Adhesives

1.0 SCOPE

This document covers guidelines for selecting electrically conductive adhesives for use in assembly of components to printed circuit boards (PCB) or similar wiring interconnect systems. The focus is on the use of adhesives as solder alternatives. The process discussion attempts to stay within the bounds of the existing solder assembly infrastructure as much as possible. Both major types of adhesives, isotropic (conducting equally in all directions) and anisotropic (unidirectional conductivity), are covered. The two major divisions of polymer adhesives, thermosets and thermoplastics, are described.

1.1 Introduction Polymers are long-chain molecules, such as epoxies, acrylics and urethanes, that are widely used to produce structural products such as films, coatings and adhesives. Although polymers occur naturally, most are now synthesized. Their properties can be tailored to meet thousands of different applications. Polymer-based adhesives are used in virtually every industry because of this capability to customize performance. Polymers have excellent dielectric properties and, for this reason, are used extensively as electrical insulators. Most wire insulation is made from polymers. Although a narrow class of conductive polymers, called Intrinsically Conductive Polymers (ICPs), does exist, their other properties do not lend themselves for use as conductive adhesives. Therefore, virtually all conductive adhesives are made by adding conductive fillers to nonconductive polymer binders.

2.0 APPLICABLE DOCUMENTS

2.1 Institute for Interconnecting and Packaging Electronic Circuits¹

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-TM-650 Test Methods Manual

3.0 BASIC TYPES AND FEATURES

3.1 Benefits and Limitations of Conductive Adhesives

Conductive adhesives are very different from metallurgical solders (the two classes of joining materials are contrasted in later sections). These differences produce a large set of benefits that are listed below. Not every adhesive presently has all of the features listed, but conductive adhesives technology

has the potential to deliver all of these benefits in a single material.

Benefits

- Compatibility with a wide range of surfaces including non-solderable ones.
- Low temperature processing; low thermal stress during processing.
- Low thermomechanical fatigue; good temperature cycling performance.
- Low or no significant VOCs.
- No residuals; high surface insulation resistance.
- Reduced pre-clean or post-clean requirements; no CFCs or washing equipment.
- No lead or other toxic metals. finer pitch capability.
- Wide processing latitude; easy process control.
- Soldermask not required.

Limitations

- Lower mechanical strength
- No component self-alignment
- Some adhesives require special finishes on parts and printed wiring boards.
- Higher electrical resistance.
- Higher thermal resistance.
- More difficult to rework.

3.1.1 Types of Conductive Adhesives The most common conductive adhesives are silver-filled thermosetting epoxies that are typically provided as thixotropic pastes. They are used to electrically interconnect and mechanically bond components to circuits. Heat is most often used to activate a catalyst or co-reactant hardener that converts the paste to a strong, electrically conductive solid. The products which conduct equally in all directions are referred to as isotropic conductive adhesives. These metal-filled thermosetting conductive adhesives have been used as die attach materials for many decades and are still the most popular products for bonding ICs to lead frames. More recently metal-filled thermosets have been formulated as component assembly materials. New polymer-based materials are now being used to replace metallurgical solders, especially for surface mount assembly.

A number of other types of adhesives have also been developed. Silver-filled thermoplastic adhesives are available in both paste and film form. The films have found use primarily as die attach adhesives. Thermoplastic pastes are made

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by dissolving polymer resins into solvents and then adding conductive fillers. Some of the commercially available thermoplastic conductive pastes can be used for component assembly adhesives, but their properties are typically not as well-suited as the thermosets. This guideline will therefore focus on thermoset systems for isotropic type adhesives. Both thermoset and thermoplastic processing will be covered for anisotropic adhesives since both types and mixed polymer systems are widely available at this time.

Anisotropic conductive adhesives represent the other major division of polymer bonding agents. The anisotropic adhesives can provide uni-directional conductivity which is always in the vertical, or Z-axis. The directional conductivity is achieved by using a relatively low volume loading of conductive filler. The low volume loading, which is insufficient for inter-particle contact, prevents conductivity in the plane of the adhesive. The Z-axis adhesive, in film or paste form, is placed between the surfaces to be connected. Application of heat and pressure to this stack up causes conductive particles to be trapped between opposing conductors on the two adherents. Once electrical continuity is produced, the dielectric polymer binder is hardened by thermally initiated chemical reaction (thermosets) or by cooling (thermoplastics). The hardened dielectric polymer holds the assembly together and helps maintain the electrical contact between conductors and particles. Anisotropic adhesive products are now being used to connect flat panel displays, TAB, flip chips and fine pitch SMDs. Since anisotropic adhesives generate different characteristics and require special equipment and processing, they will be covered separately in more detail later.

3.1.2 Comparison of Metallurgical Solder and Conductive Adhesives The metallurgical solder joint, typified by tin/lead solder, is made up of a continuum of metal phases and intermetallic compounds (Figure 3-1). All of the several phases formed in the solder joint are electrically conductive. The solder bonds directly to the metal of the component termination and the circuit board. Usually, a small amount of the surface metals dissolve in the molten solder. Thin circuit and component finishes, especially gold plating, dissolve into solder and become part of the junction alloy. The solder process requires that any oxide on the surfaces to be joined be removed. Soldering of oxidized surfaces therefore requires an oxide removing agent known as flux. Any residual flux must later be removed. The solder joint is complex and its composition is affected by the adherents, temperature, flux, duration of heating and many other factors. The adhesive junction, described in the next paragraph, is much different.

Conductive adhesives do not normally form metallurgical interfaces, although junctions of newer high stability types have not been studied in enough detail to preclude the possibility. The basic electrical path is through the adhesive's

conductive particles that contact one another and the two adherent surfaces (Figure 3-2). The overall result is to create numerous pathways, but with each path made up of a large number of mechanical contacts. Conductive adhesives are composites of discrete conductive particles in a matrix of polymer adhesive. The filler provides conductivity, both electrical and thermal, while the polymer produces the mechanical performance characteristics. Although the adhesive should be viewed as an integrated system, the separation of mechanical and electrical properties provides advantages over solder, but also disadvantages. The electrical and mechanical performance can be independently modified and much more tailoring is possible than with solders. However, this independence also means that good mechanical performance is no assurance of electrical integrity. The next section highlights the differences.

3.1.3 Key Differences Between Isotropic Conductive Adhesives and Solder

3.1.3.1 Mechanical-Electrical Independence The first rule of conductive adhesives is to set aside all the knowledge and rules of metallurgical solders. The new user of conductive adhesives often encounters problems as the results of the Solder Paradigm. Solder has been the standard of electronic assembly for such a long time that all specifications, test methods, application processes and expectations are tied to tinlead solder. Adhesives, because of their composite nature, behave much differently. The most important difference for conductive adhesives is the *independence* of mechanical and electrical properties. However, while good mechanical values do not guarantee the electrical performance, a reasonably strong bond is a prerequisite for electrical adequate performance. Mechanical force is needed to keep mechanical interfaces in close contact as can be seen from the electrical pathway diagrams. Solder always gives good electrical performance if the junction has good mechanical properties. A strong adhesive bond is no assurance of good electrical performance.

Electrical and mechanical performance of adhesives must both be tested. Adhesives with low filler loading may show superior mechanical properties and have no electrical conductivity. IPC test procedures (which may be found in IPC-TM-650) address this dichotomy and for this reason, more testing is required for adhesives than solder. A second important difference deals with junction stability. While solder often loses mechanical performance during accelerated aging, especially thermal cycling, conductive adhesives can show a marked reduction in electrical conductivity while maintaining mechanical properties. Conductive adhesives must be tested for junction stability, especially if a new component or circuit board finish is involved. Surfaces, like copper and solder coat, are especially sensitive to junction instability. The particle contact