



Mini Briefing

Adhesives in Electronics

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Abstract

The use of adhesives and sealants in the electronics industry is now widespread and they contribute directly not only to the manufacture of electronics products but also to their long-term operation and longevity. Major uses of adhesives in the electronic industry include bonding of surface-mount components (SMCs), wire tacking and potting or encapsulating components. This briefing reviews the main types of adhesive in use and their applications.

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1.0 Introduction

The basic building block of the electronics industry is the printed wiring board or, as it is more commonly called, the printed circuit board (PCB). The PCB makes use of adhesive materials in bonding surface-mount components, wire tacking, conformal coatings and in encapsulating (potting) components.

A typical PCB is a multi-laminate reinforced plastic board (typically epoxy resin/glass fibre) with a protective plastic coating (permanent solder mask). Initially, boards had circuitry on only one side. They were manufactured with drilled holes for interconnecting multi-layer boards – ‘through-hole’ technology. Board and component miniaturisation led to ‘surface-mount technology’ in the 1980s. With surface-mount technology, component contacts are soldered directly to pad areas on the surface of the board, making it possible to eliminate drilled holes and through-board connections.

For the technologies described above, major uses for adhesives, mainly organic (i.e. carbon-based) in nature, are as follows:

- bonding of surface-mount components (SMCs)
- wire tacking
- potting and encapsulating electronic components
- conformal coating of circuit boards

2.0 Bonding operations

These applications are considered below.

2.1 Surface-mount devices (chip bonding)

Surface-mount devices (SMDs) are placed on small beads or dots of uncured adhesive and then cured in place by heating or exposure to ultraviolet (UV) radiation. This secures the SMDs firmly in place during subsequent process operations such as leaded-device insertion or cleaning, until they can be soldered to the board’s solder pads. Surface-mount adhesives can serve two functions: they act as a processing aid (e.g. holding a part temporarily until it can be permanently attached by soldering); and they can also provide stress relief to solder connections during service to prevent premature failure of the electrical connections. After soldering, the now redundant adhesive must not affect the circuitry in any way.



To meet the requirements for successfully bonding SMDs, the following properties are required of the adhesive:

- long shelf life
- suitability for high-speed dispensing of very small dots of consistent profile and size
- non-stringing
- high wet strength
- rapid curing
- non-slumping during heated cure cycle
- high strength and good flexibility
- good electrical properties after curing

Depending on the exact function of the surface-mount adhesive, it can be electrically conductive, electrically non-conductive and/or thermally conductive. Three chemical types of adhesive are commonly used for surface-mount component bonding: acrylics, epoxies and urethane acrylates. These adhesives, together with other types used in electronics applications, are discussed in greater detail below.

Ideally, surface-mount adhesives need to be of the single-component type. This avoids problems of pot-life, air entrapment and changes in viscosity normally associated with dual or multi-part systems. Usually, the adhesives will cure within two minutes at elevated temperatures safe for use with PCBs and associated components.

2.2 Wire-tacking adhesives

Wired connections are common on PCBs. The use of wires not only allows replacement but also augmentation of printed wiring on the PCB. Some of the reasons for this are as follows:

- to overcome a design flaw discovered during board testing
- to upgrade or modify a PCB
- to repair board damage or overcome the effects of improper manufacture.

Usually, an insulated wire is stripped and soldered at each end to pads and component leads, then bonded or staked to the board substrate. The bonding prevents the wire from moving around and acts as a structural adhesive in environments where vibration could occur.

The types of adhesive which can be selected for wire tacking include cyanoacrylates (so-called 'super-glues'), epoxies and light-curable acrylics. In practice, cyanoacry-

lates are widely used, often in conjunction with a suitable activator to speed the cure time to around 20–30 seconds.

2.3 Potting and encapsulation

Potting is a method of filling small spaces or surfaces with a material that will protect components from physical and environmental damage. Potting components also provides additional insulation capability.

Potting compounds usually exhibit good chemical properties and high adhesion to plastics and metals, these being the materials of construction of the containers and also of the components.

Typical resins used for potting are epoxies, polyurethanes, silicones and acrylics, the latter usually being UV-curing formulations.

In addition to potting, there are other methods of encapsulating electronic components, namely casting and moulding. Casting uses the same type of adhesive resins as potting, although the container (outer casing) is usually removed after the resin has cured, unlike the potting process where the container becomes an integral part of the component. Moulding usually involves the injection of pre-melted thermoplastic resins into a mould containing the electronic components or circuitry.

2.4 Conformal coatings

Conformal coatings, whilst not strictly the result of an adhesive bonding process, utilise the same chemical types of resin (e.g. epoxies, polyurethanes, acrylics and silicones). The aim is to produce a coating that strongly adheres to and covers all the board and the components on it. A conformal coating is typically used to protect the board from environmental factors such as:

- corrosion (e.g. of solder joints)
- moisture and mildew
- changes in service temperature (typically from -40°C to $+200^{\circ}\text{C}$)
- short circuits.

Conformally coated boards are protected from environmental damage and, in addition, mechanical and electrical interference.



3.0 Adhesive types used in electronics

Three different processing phases must be considered when selecting an adhesive for electronics (or any other) applications: the uncured or liquid-resin phase, the curing (transitional) phase and the cured or solid-material phase. The performance of the cured adhesive is ultimately the most important because it affects reliability.

The method of applying the adhesive is also of great importance, in particular because of the need to ensure that the correct amount is applied in the correct place. Major methods of applying adhesives in electronics applications are screen printing (squeezing the adhesive through patterns in a screen), pin transfer (using multi-pin grids which convey patterns of adhesive drops to the board) and syringe application (in which shots of adhesive are delivered by a pressure-regulated syringe). Syringe application is probably the most popular method, usually by way of electro-pneumatically-controlled syringes for moderate production of many different types of PCB.

The various types of adhesive will now be considered.

3.1 Electrically conductive adhesives

By their nature, most adhesives, both organic and inorganic, are not electrically conductive. This applies to the main types used in electronic applications such as epoxies, acrylics, cyanoacrylates, silicones, urethane acrylates and cyanoacrylates. However, in many applications, including integrated circuits and surface-mount devices, electrically conductive adhesives are required.

The usual way of converting non-conductive adhesives to electrically conductive materials is to add suitable filler to the base material; usually the latter is an epoxy resin. Typical fillers used to confer electrical conductivity are silver, nickel and carbon. Silver is the most widely used. The conductive adhesives themselves are either in a liquid or pre-form (reinforced adhesive films die-cut before bonding to the shape required).

There are two types of electrically conductive adhesives – isotropic and anisotropic. Anisotropic adhesives conduct in all directions but an isotropic adhesive conducts in the vertical (z-axis) direction only and is thus uni-directional. The isotropic adhesives lend themselves to fine-line interconnection. It should be noted that, useful as conductive adhesives are, they cannot be simply ‘dropped in’ as

solder alternatives. They are not good with tin (or tin-containing alloys) or with aluminium, nor where there are large gaps or where they are likely to be exposed to wet (damp, moist) conditions in service.

3.2 Thermally conductive adhesives

Miniaturisation of electronic circuitry may result in problems of heat build-up, which can cause premature failure of electronic components if their maximum operating temperature is exceeded. Thermally conductive adhesive can be used to provide a heat-conducting path, fastening transistors, diodes or other power devices to suitable heat sinks to ensure such a heat build-up does not occur.

Metallic (electrically conductive) or non-metallic (insulating) powders are blended into the adhesive formulation to make high-viscosity (paste) adhesives, which are highly thermally conductive (in comparison with unfilled adhesives). The most common thermally conductive systems are formulated with epoxy, silicone and acrylics.

3.3 Ultraviolet-curing adhesives

Light-curing adhesives, coatings and encapsulants are being used in the electronics manufacturing industry with increasing frequency because they meet the requirements for materials and processing within this industry. Those factors include environmental demands (environmentally-damaging solvents and additives are not required), manufacturing-yield improvement and product cost. Light-curing adhesives are simple to use, and are quickly cured without the need for elevated temperature curing.

The adhesives are normally acrylic-based formulations and contain photo-initiators which, when activated by ultraviolet radiation, form free radicals to initiate the polymer-forming (curing) process. Ultraviolet light must be able to penetrate into the uncured resin – a drawback of light-curing adhesives. Deposits of resin that are dark-coloured, inaccessible or very thick are difficult to cure.

3.4 Other adhesive types

The adhesives mentioned above are the major types used in normal electronics manufacturing procedures. There are others, however, which are still quite widely used:



- *Cyanoacrylates* These have already been mentioned for their use in wire-tacking applications. Cyanoacrylates ('super glues' as they are popularly known) are single-part adhesives, which cure very rapidly when exposed to moisture in the air. The use of these adhesives with an activator speeds up the curing process even more.
- *Silicone resins* More a sealant than a structural (load-bearing) adhesive, silicone resin is used as an encapsulant as well as for conformal coating. Silicone resins have very good low and high heat tolerance (typically -60°C to +200°C) but can cause problems in secondary operations (painting, bonding etc.) because of the release of low-molecular-weight silicone compounds, which contaminate surfaces over a very wide area.
- *Polyimides* These are very-high-temperature resins (tolerating up to 300°C or so), which are used in high-technology electronics applications (typically aerospace) for wire coatings and flexible circuits. They are usually used in the form of polyamic acid precursors and require difficult and prolonged curing cycles before forming the typical flexible, heat-resistant polyamide material.

There are even more adhesives, which have found use in electronics applications and doubtless more will follow. The types mentioned above, however, are well established and widely used and form an integral part of the electronics-manufacturing industry.

4.0 Conclusions

The electronics market comprises many different industries including telecommunications, consumer, computer, defence and automotive sectors, all using the PCB as the basic building block for their products. Some 50 years ago, the amount of adhesives used in the production of PCBs and other electronic components was minimal. Now the absence of adhesives from electronics manufacturing is unthinkable. Environmental, health, cost and speed of manufacture are driving factors for the continuing and ever-expanding use of adhesives in the industry.

The days when solder was the exclusive joining material in electronics assembly have long gone. The aim now is to focus on the use of adhesives as solder alternatives. There is still some way to go, as the adhesive will need to take over the mechanical properties of the solder and be electrically and thermally conductive to a very high degree.

One thing is certain however – the use and development of adhesives in electronics their will continue to grow.

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