Flexible, Reworkable, Conductive Adhesive/Coating For Interconnection Applications

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Recent advances in materials formulations have translated into improved properties in areas like thermal expansion ranges. These improved properties have in turn contributed to advances in developing technologies. Following are several recent innovations.

Thermally Conductive Adhesives for SEM Board And Backplane Applications

As the density of integrated circuits (ICs) increases, interconnection and circuit board densities have similarly increased to make these electrical circuits functional. This overall increase in circuit density and functionality has intensified the need for improved thermal dissipation.

Thermal dissipation and thermal management requirements, important at all levels of electronic packaging, sometimes reach into interconnection areas as well. An example in the die attach area is the use of a tape-automated bonding format for IC packaging. Because of the dense pitches, shorting or "bridging" becomes much more of a problem than in traditional die attach. In this case, the use of controlled flow film adhesives have contributed to successful die attach without the problems of excess flow or bleed-out encountered with pastes or normal high flow adhesives. Some newer applications require the use of thermally conductive but electrically insulating adhesives in place of the traditional electrically conductive adhesives.

It is becoming common in newer electronic packaging to eliminate the use of forced air cooling. Thus it becomes a necessity to remove the heat to the outside world by heat sinking or conducting it to a large thermal mass.

In ceramic hybrid packages and densely populated printed circuit (PC) boards, the requirements of thermal dissipation have made the use of the more thermally conductive metals such as copper and aluminum as base plate or heat sinks a necessity. This use of these materials has created problems such as delamination, circuit fractures and other failures because the thermal expansion mismatches between the circuit boards and substrates or base plates results in stresses on these components.

Typically, alumina or other ceramic substrates have a coefficient of thermal expansion (CTE) in the range of 7 ppm

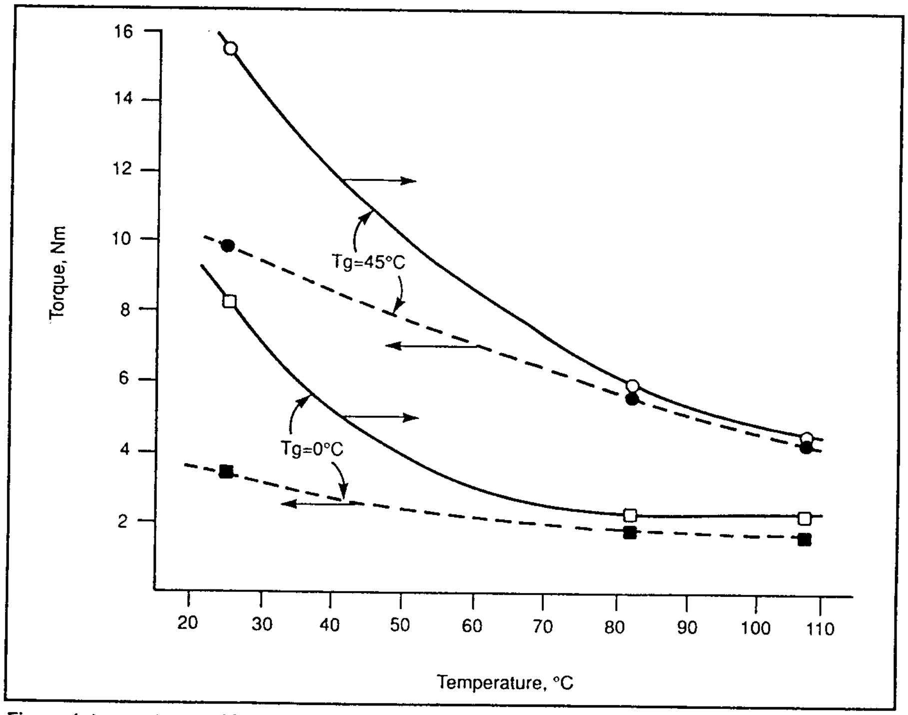

Figure 1, torque test and lap-shear data on adhesives. (From a paper presented at SAMPE '87, by J.M. Kolyer et. al.)

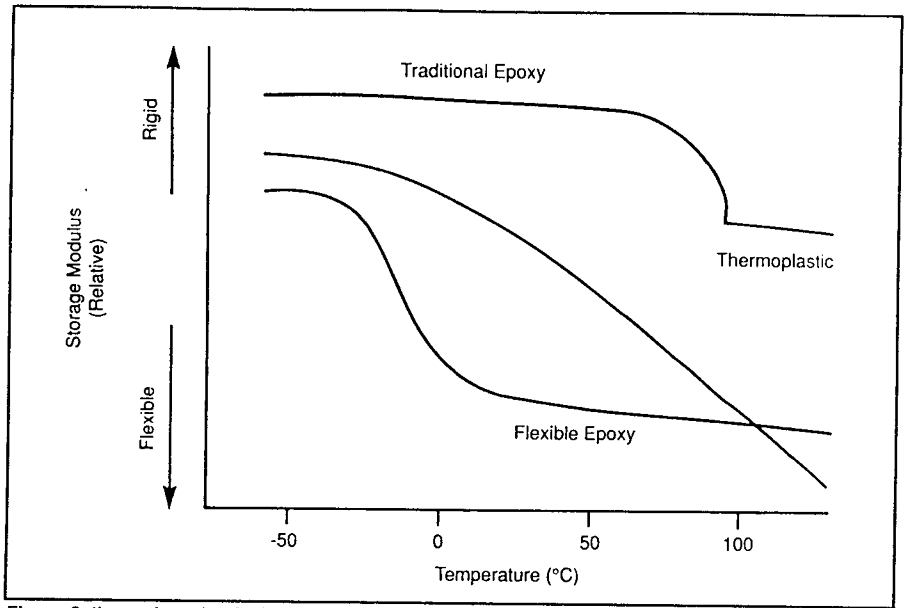

Figure 2, thermal mechanical properties of different classes of polymer materials.

per degree Kelvin; FR-4 materials have an X-Y axis CTE in the range of 15 ppm per degree Kelvin, while aluminum has a CTE of 25 ppm per degree Kelvin. With large areas, the stress can be calculated and measured to be in the range of 50,000 psi during thermal cycling. While there are three-dimensional models available for this type of calculation, a simple one dimension elastic model will give similar values but in terms much simpler to understand. The adhesive can be solder, glass-frit, epoxy, etc.

During assembly, these materials reach an equilibrium at their bonding or curing temperature. This is the point of zero stress on the components. When the assemblies are cooled down, the adhesive normally having a higher CTE will contract much faster and thus exert a compressive stress onto the substrates being bonded. This stress level will continue to increase while the assemblies are being cooled down to -55°C during thermal cyclings.

The stress can be estimated as the strain being induced by the differential thermal expansion or contraction, over the temperature difference between the curing and operational or testing temperature, multiplied by the modulus of the adhesive being used. This simple model can be illustrated in equation(1) that follows:

$$\sigma = E_A \times E_A$$
$$= (\alpha_A - \alpha_S)\, \Delta T \times E_A$$

E_A = Modulus of Adhesive
E_A = Strain
α_A = CTE of Adhesive
α_S = CTE of Substrate

Materials such as tin/lead will have a modulus in the range of 10 to 20 million psi, while the traditional epoxies will be in the range of 1 to 10 million psi. With a differential CTE of more than 10 ppm per degree Kelvin, and temperature differential from equilibrium being in the range of 100 to 200°C, the magnitude of stress can be well over 10,000 psi; thus, it is not surprising that the circuits sometimes fail, delaminate, warp, etc. under thermal cycling or simply during the cool-down cycle. It is also not surprising that tin/lead solder joints will fatigue over time.

Manufacturers are now successfully addressing these stress problems with flexible non-silicone epoxy adhesives, in both film and paste formats. The moduli of these adhesives are in the range of 0.02 million psi. These highly forgiving and compatible adhesives with wide applications in electronic applications over the last three years give stress levels of less than 250 psi.[1]

Military Connectors Applications

With military connectors, the termination between the wire braiding and backshell may need a tighter EMI shield than obtained with pressure or in interference-type fits. In this case, the flexible conductive adhesives can be used very effectively. The fact that the adhesives are flexible permits them to be reworked, making this type of EMI potting more amenable. Their rework temperatures and bond strengths are summarized in figure 1.

Conductive Adhesive for VLSI/ULSI Interconnection

With VLSI and ULSI packagings, there are basically two different problems: one is the stress problems associated with CTEs of the materials, and the other is the bridging problem associated with the close pitches between interconnection.

The first problem of stress becomes acute when the dice sizes increase to more than 1 x 1 cm. In this case, the use of a copper lead-frame becomes somewhat difficult. The flexible conductive or thermally conductive adhesives have proven to be one of the few solutions to this problem.[3]

In the case of bridging between the pitches, the problem can be reduced with the use of film adhesive if the dice are large enough for easy handling. A suitable size will be in the range of 0.25 cm or larger. The film adhesive being defined in both thickness and material contents, when properly processed, provides a defined bonding thickness.[3] It not only provides a technical solution in the longer run, but also has the potential to lower costs because there is less waste, and assembly processes are faster. In addition, a film adhesive also eliminates all potential of human allergic reactions to conventional epoxy pastes.

Some formats of IC packaging allow the use of an electrically insulating but thermally conductive adhesive. The use of diamond-based adhesives in flexible epoxies have provided needed technology for this type of IC assembly. It is obvious that both the film adhesive and the diamond-based adhesive can be used effectively for TAB devices.

Conventional and Uni-Directional Conductive Adhesive for Flexible Connectors

With many flexible cables and connectors, the use of a flexible adhesive can mean greater reliability because less thermal stress is introduced by the CTEs of the flexible connectors and the circuits during temperature excursions.

Uni-directional or Z-axis conductive adhesives are being developed for close pitch interconnections. These materials will simplify assembly and eliminate the requirement for a large number of individual components for varying sizes of connectors. This could result in lowering the cost of manufacturing and increasing the speed and ease of assembly. These materials include both pastes and films for the high impedance devices such as displays.[4]

Model for Modulus Temperature Dependence

While most materials reflect the temperature dependence of their properties, polymers exhibit some of the more prominent examples of these changes because of their glass-transition temperatures and visco-elastic characteristics. In order to understand the novel characteristics involved in this new class of "zero-stress" adhesives, figure 2 displays a plot of the temperature dependence of different polymers, such as thermoplastics, and of thermosets, such as epoxies.

The glass transition temperature characterizes a material's change from a glassy, rigid state to a rubbery, elastic state. The exact temperature of the transition depends on molecular structure, and cross-linked density, in the case of thermosets.

The novel "zero-stress" flexible adhesives have a flexible molecular back-bone structure and a controlled cross-linked density to give them a Tg of less than -25°C. This gives them the desirable flexible characteristics of a silicone without its migrational and outgassing problems. In fact, some of these materials have been tested for the NASA outgassing requirement with less than 0.3% total weight loss and less than 0.03% of condensable volatiles.

Hyper-Conductive Flexible Coatings For EMI Wire Braiding Replacement

In the avionics field, many times the cable itself can have substantial weight because of the wire-braiding used to provide EMI shielding. A highly conductive silver-filled coating has a density of 3.5 g/c^3, much less than most metal wires.

Because of the potential for continuity of shielding provided by a highly conductive coating, it can also have much better shielding in the high frequency gigahertz ranges.

The question is whether a silver or other metal-filled coating will provide the same type of shielding effectiveness as metal braiding in general. Traditional coatings, for use in commercial FCC-type applications, have resistivity in the range of 0.005 Ω/cm, or roughly 2 ohm/square, and will provide 40 to 60 dB shielding. Traditional metal wirings have a resistivity of 0.000003 Ω/cm and will provide more than 80 dB shielding when properly joined together.

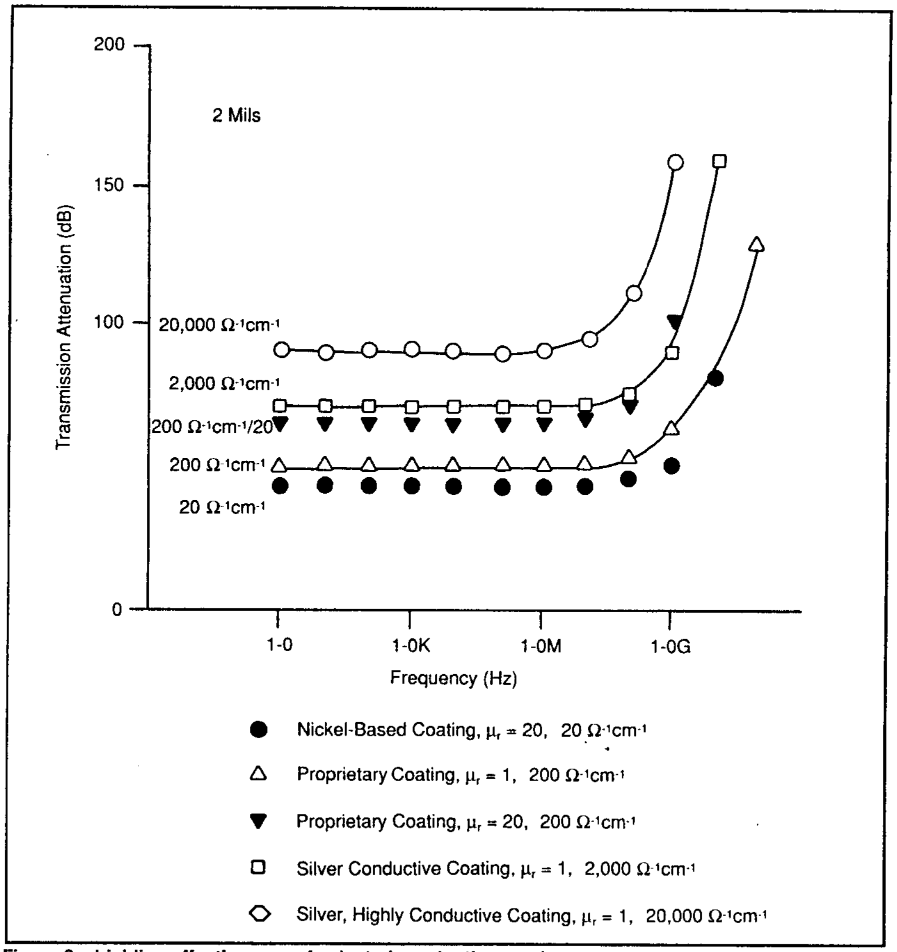

Figure 3, shielding effectiveness of selected conductive coatings.

New improved-conductivity coatings have lowered the resistivity to the 0.00002 Ω/cm range. Coatings in this range have been proven to provide more than 75 dB shielding in the range of 1 MHz to 10 GHz. In some applications, because of their ease of application, they have been proven to give better shielding effectiveness than some metal braids.

Figure 3 is a plot of the plane-wave theoretical shielding effectiveness as a function of conductivity of the coatings. It is clear that a stable conductive coating can be a very cost effective means of EMI shielding. These theoretical predictions have been confirmed in the 1 MHz to 10 GHz range with the improved conductive coatings.

It is also possible to use these coatings to add EMI shielding to plastic housings, traditional silicone door gaskets and molded polyurethane flat flexible cables.

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