



Potting Compounds Protect Electronic Circuits

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Product reliability is an absolute must for manufacturers to succeed in today's competitive marketplace. As customers demand ever increasing levels of performance at lower unit costs, it becomes increasingly challenging to ensure that electronic circuits operate as designed for a prolonged period of time. Delicate components, densely populated printed circuit boards (PCBs), confining packaging, and highly demanding service environments have the potential to lead to increased failure rates as a result of excessive heat build-up and electrical interference.

Hostile conditions jeopardize product reliability

Electronic equipment is often subjected to one or more stresses that may impair performance. Prolonged exposure to high temperatures or cryogenic conditions, chemicals, rigorous thermal cycling, mechanical shock, thermal shock, and other conditions can adversely affect electronic devices — causing them to fail.

During manufacturing and assembly, components must often withstand high soldering temperatures and are sometimes exposed to cleaning agents and other chemicals that can interfere with circuit operation. Additionally, electronic assemblies are commonly subjected to rigorous qualification testing. This includes challenging conditions such as extreme heat, chemical exposure, thermal cycling, thermal shock or mechanical shock, excessive vibrations, all of which can cause product failure. Often qualification testing is more rigorous than the actual operating conditions.

Potting isolates electronics from the environment

Potting and encapsulation compounds impart the highest level of protection from environmental, thermal, chemical, mechanical, and electrical conditions. Designed to completely encapsulate a component, module, or PCB, these specially formulated compounds effectively shield the unit from its surroundings while providing structural support. Potting compounds offer a higher level of physical,

chemical, electrical, and temperature protection than do conformal coatings. The flip side is potting can often add extra processing time, cost and weight.

Epoxies and silicones are among the most frequently used potting compounds. These can be applied to PCBs, capacitors, power electronics, LED lighting, sensors, and more. Some of the desired properties include good adhesion, excellent electrical insulation, thermal stability, superb chemical resistance, low shrinkage upon curing, an appropriate coefficient of thermal expansion (CTE), and suitable viscosity for the specific application. Formulations can be blended to provide a balance of these and other properties through careful selection of resin, agent, and fillers.

Potting, Casting & Encapsulation

Potting compounds can be applied to an electronic device in one of three ways: potting, casting, or encapsulation. The most commonly used method is potting, in which the device is placed in a "pot", or case, and a liquid potting compound is poured into the case until it is filled to the brim. The case is left intact, becoming part of the finished unit. Casting is similar to potting, except that instead of a case, a mold is used and is removed after the compound hardens. Casting is used to create a molded unit. Encapsulation involves dipping the component into a resin system so that a thick coating forms around the component.

Although the methods differ somewhat, in each case, the component is completely surrounded by the protective potting compound. The terms potting and encapsulation are often used generically to describe the complete covering of an electronic component with a potting compound via any of the three methods.

Variety of potting formulations to suit diverse application needs

A critical part of choosing the right product is prioritizing the requirements and realizing that tradeoffs are associated with choosing a material. That is to say, a balance must be developed between the final properties with handling and processing issues such as open time, viscosity, cure schedule, and other factors.

Epoxies are the most commonly used material for potting and encapsulation, due to their wide range of properties and unmatched versatility. Epoxies offer exceptional chemical resistance, excellent physical properties, and strong adhesion to metals, most plastics, ceramics, and composites — materials commonly used for potting housings. They typically have superior dielectric properties and are normally thermally insulative, but can be made thermally conductive and electrically insulative when needed. They can also be formulated to withstand thermal cycling, stresses, and shocks while retaining their excellent dielectric properties. Although epoxies are usually considered to be rigid and permanent in nature, they can be made more flexible when required, with some grades exhibiting enough flexibility to allow for possible retrieval of a component. However, when epoxies are formulated to be more flexible, chemical and temperature resistance are invariably compromised.

Epoxies can be engineered for use in potting applications that call for very specific characteristics, such as optical clarity, flame retardancy, thermal conductivity, or low outgassing properties, while retaining their electrical isolation capabilities. Specially formulated flame resistant epoxies that are certified to meet UL 94V-0 specifications are self-extinguishing and offer superior electrical insulation properties, making them ideal for potting power supplies, signal transformers, and other high power electronic devices.

The unparalleled versatility of epoxies is exemplified by their wide service temperature range. Some grades can withstand cryogenic conditions while others resist temperatures up to 500°F. However, unique B-stage epoxy compounds offer high temperature resistance and are more flexible than typical high heat resistant epoxies. Normally, epoxies that resist higher temperatures are rigid. They can withstand rigorous thermal cycling and thermal shock, but require more involved processing in order to realize their special properties. For example, they must be converted to liquid from solid state. Most importantly, B-stage materials have lower exotherm than typical one part epoxies, and are suitable for larger castings. Fillers can be added to achieve other performance properties such as thermal conductivity and enhanced dimensional stability.

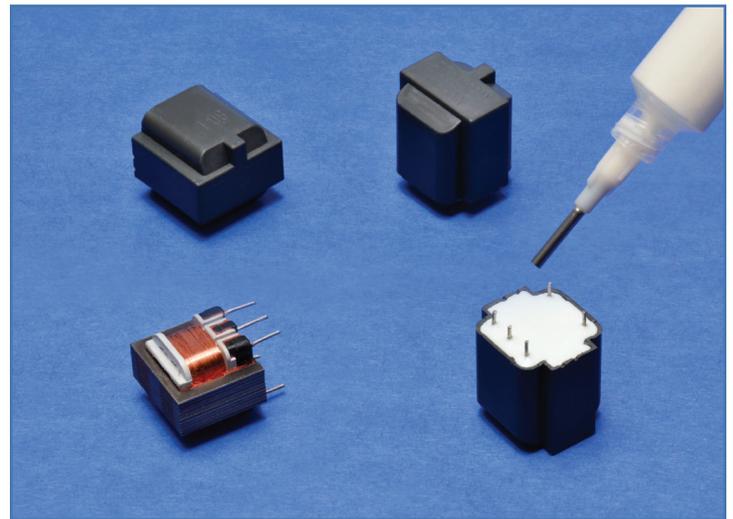
Epoxies are clearly the best choice when chemical resistance, good physical strength and first-rate electrical insulation properties are required. Because epoxies can

withstand repeated temperature excursions above the glass transition temperature (T_g), a particular grade should not be ruled out for applications that involve only shorter dwell times at higher temperatures. For instance, an epoxy with a T_g of 150°C can easily withstand repeated excursions of many hours above 200°C, depending upon the nuances of the application.

Epoxies are commonly used with fillers to lower shrinkage, enhance dimensional stability and improve abrasion resistance. The use of fillers is the critical factor for obtaining thermal conductivity while retaining electrical resistance. Through careful selection of chemistry, additives, and fillers, formulators are able to develop epoxy compounds with properties that are tailored to address most application needs.

Silicones offer an unparalleled combination of high temperature resistance (up to 400°F), superb electrical properties, and flexibility, but sometimes require the use of primers to improve adhesion. They are often selected for their unmatched ability to resist thermal shock and repeated thermal cycling. Softer than epoxies, silicones exert less stress on sensitive electronics and also make it possible to retrieve components that need repair or removal. The properties of silicones can be adjusted through the addition of fillers, such as those used to achieve thermal conductivity and flame retardancy.

UV curable potting compounds have a unique chemistry that allows for ultra fast curing, normally under a minute. These materials cure through exposure to a UV light source. The thinner the layer, the faster the rate of cure. If the area being potted contains shadowed out portions, a secondary curing mechanism, often utilizing heat, is required. The secondary cure temperature ranges from 80°C to 125°C for up to 30 minutes. This system is called a dual cure UV.



Thermally conductive, electrically insulative epoxy potting compound provides superior heat dissipation properties.

Both UV and their dual cure counterparts can cure rigid or flexible. They have good electrical insulation properties and are optically clear. However, fillers cannot be added to these kinds of systems and their usage is limited by depth of cure, rarely exceeding ¼ inch. Invariably, they are used selectively in special small encapsulating applications.

Thermal and geometric factors impact processing

To ensure the optimum level of protection and avoid harming delicate components, care must be taken when applying and curing potting compounds. Some materials require surface preparation and primers in order to achieve good adhesion. During application, the liquid potting material must flow easily so that it completely covers the component, leaving no voids. If air becomes trapped in the housing, the moisture it contains may cause corrosion — eventually leading to component or product failure.

Removing air bubbles is very important. There are two techniques that are commonly used: vacuum degassing or centrifuging. It is possible to degas either after the material is mixed or after it is applied. The best technique for vacuum degassing is referred to as “bumping” which is alternately pulling and relaxing a vacuum in 30 to 60 second cycles. Centrifuging is very straightforward. The mixed material is placed in the centrifuge and spun for 10 to 15 minutes at 500 to 1000 rpm.

These techniques may not be necessary for potting compounds with very low viscosity, since air bubbles may be negligible. However, in certain pottings, higher viscosity systems are more desirable due to geometry or design issues, so vacuum degassing or centrifuging remains a critical processing step.

One popular method of eliminating degassing or centrifuging is to package the compound as a premixed and frozen system. These epoxies are mixed and centrifuged prior to freezing. They are typically packaged in small syringes (3 to 10 cc’s) and shipped in dry ice. The storage temperature is -40°C. Premixed and frozen epoxies are normally used in very small potting and encapsulation applications where ultra precise dispensing is needed.

Electronics are becoming smaller. As such, the use of premixed and frozen epoxies are becoming increasingly popular. In fact, special dispensers are now available allowing for fractions of a gram to be used in an encapsulation.

The geometry of the unit and its housing are also important considerations when applying potting compounds. Potting compounds cure exothermically; that is, they give off heat as the chemical reactions that link their polymer chains

take place. With deeper castings, more heat is generated, and the reaction goes even faster. Because most potting compounds do not dissipate heat, faster reactions result in higher internal temperatures — which can damage heat sensitive components. This is why depth of cure is such an important consideration in potting applications.

Potting compounds have relatively low shrinkage as they transition from a liquid state to a solid during cure. Filled potting compounds exhibit the least amount of shrinkage, since only the polymer compound — and not the filler — shrinks during cure. In general, faster processing is not necessarily better for potting and encapsulation because faster reactions result in more exotherm, higher shrinkage, and less open time. Faster curing compounds often cannot be cast more than ¼ to ½ inch thick because they get too hot. Other than adding fillers, one can reduce shrinkage by modifying the chemical formula to reduce exotherm, or by adjusting the design.

Curing characteristics are of paramount importance to successful potting

Most epoxy and silicone potting compounds are two-part systems (resin and hardener). They take 24 to 48 hours or longer to cure, although the cures can be accelerated by adding heat. One part, no-mix systems can also be used for potting although their use is limited because their curing temperatures are typically 125°C to 150°C. These temperatures can damage electronic components. One part epoxies are very exothermic and this can induce thermal damage as well. The B-staged potting materials are the exception. While they have unique and very attractive properties, the processing is slightly cumbersome because they must be converted from a solid to liquid to use.

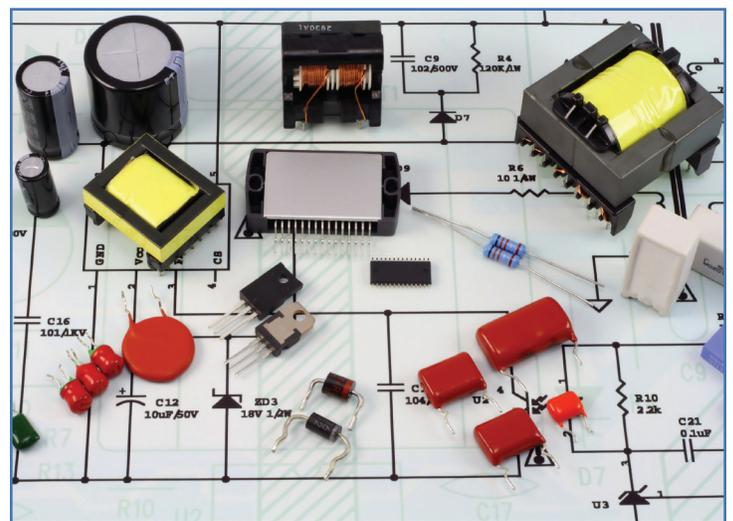


Figure 1: Proper application of potting compounds extends the functional life of electronic components and PCBs.

Reviewing product selection methodology

To summarize, the performance requirement profile of the system is paramount. If chemical resistance is required, an epoxy is the way to go. If thermal cycling and thermal shock, along with high temperature resistance are needed, then silicones are the system of choice. With each material, the importance of electrical properties cannot be overemphasized. Measurements of dielectric strength, dielectric constant, volume resistivity and the dissipation factor are often critical in selecting the best material.

Other factors that must be considered are the service temperature range, low outgassing requirements, optical clarity, thermal conductivity, flame retardancy, and biocompatibility, among other factors.

Other major factors are product handling issues, including open time, viscosity, and flow properties. Ultimately the selection is based first and foremost on the overriding performance requirements involved.

Selecting a potting compound that addresses all the needs of a specific application without harming the electronics can be quite complicated. The art of choosing a potting material depends on both properties and handling, and any design should strike a balance — achieving suitable protection without using excessive potting material. Formulators are well equipped to advise on the optimal choice of potting compound for a given situation.

Potting compounds broaden the scope of application environments

Competing demands for higher performance, lower unit costs, and enhanced product reliability are compelling designers to view potting and encapsulation compounds as essential ingredients in electronic systems and devices. By cushioning delicate components and protecting them from extreme temperatures, potting compounds make it possible for electronics to withstand harsh manufacturing processes and operate reliably in hostile — even abusive — settings. Through careful selection of an appropriate compound, electronics manufacturers can ensure their products operate as designed in ever more challenging conditions.

Because of the miniaturization of electronics and components becoming smaller, the dispensing of potting and encapsulation materials through the use of premixed and frozen syringes is becoming increasingly widespread. Most significantly, the B staged epoxy, with its unique blend of properties, is often a new and vibrant approach applied to many difficult applications.

For further information on this article, for answers to any adhesives applications questions, or for information on any Master Bond products, please contact our technical experts at Tel: +1 (201) 343-8983.