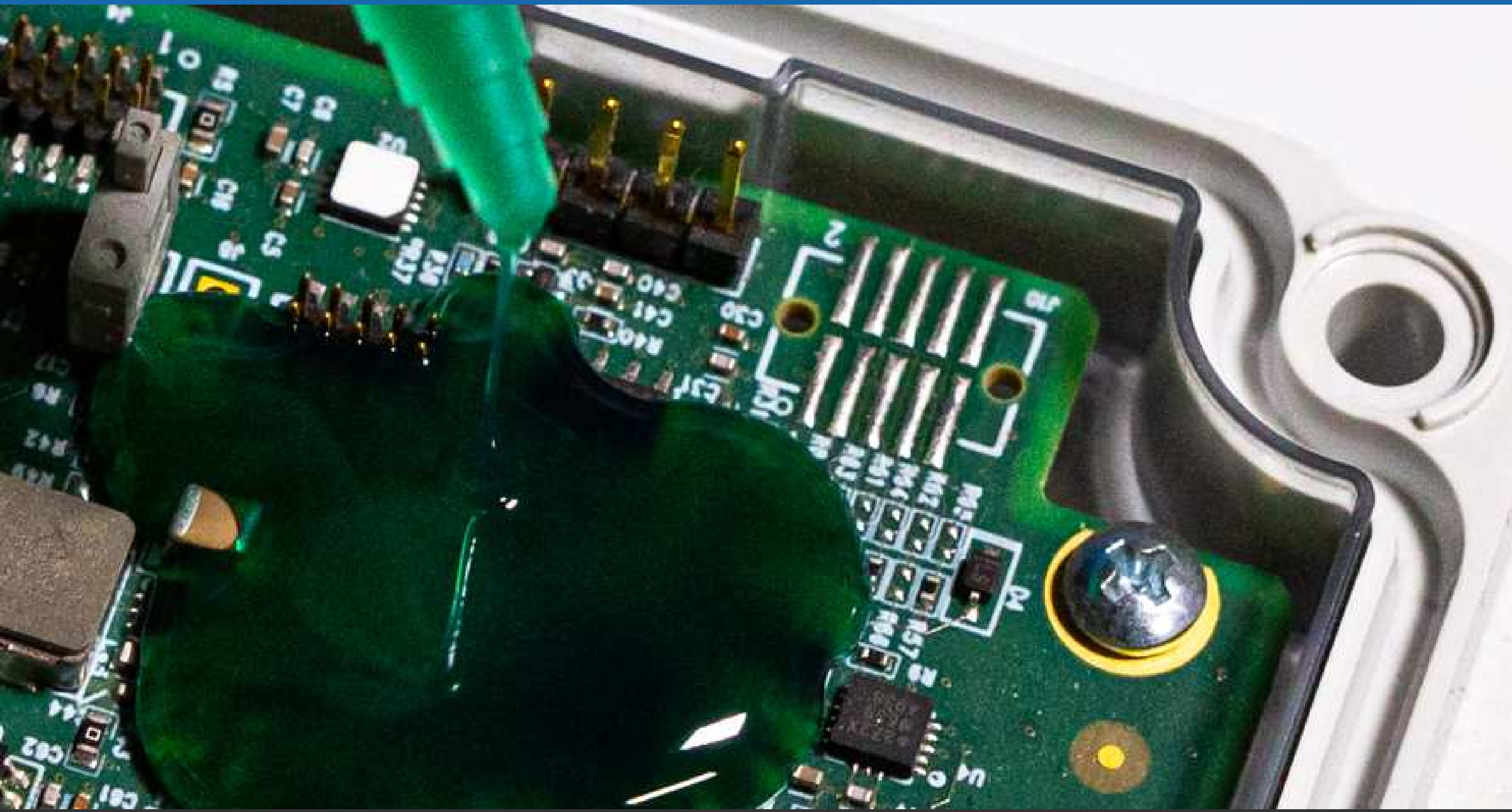
EFI POLYMERS

Engineering Reliability with Epoxies and Urethanes



An overview of potting and encapsulating electronics with epoxies and urethanes.

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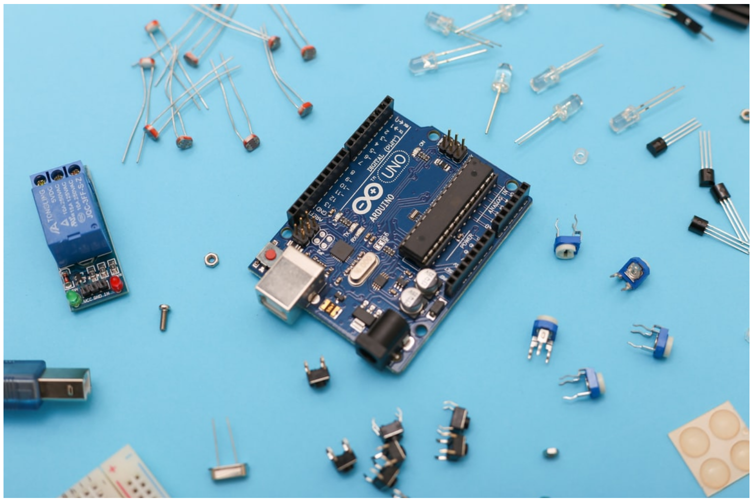
Protecting Electronics in a harsh Environment



As automotive, battery, and electronics technology continues to develop, the need to push more power and capability through electronics grows. As we continue to rely more and more on electronics, the need to protect those electronics from heat, water, dirt, dust, vibration and other contaminants also grows.

Epoxies and urethanes have been used to protect electronics for over 50 years. However, many companies view potting and the potting process as difficult, expensive, and prone to quality issues.

This white paper seeks to provide an overview of potting materials, and how to better incorporate them into your manufacturing process including how potting materials help with thermal management, how physical properties impact the finished parts, and the importance of designing with processing in mind.

Potting Materials Overview

There are many different types of materials and products used to protect electronics from the environment. One of the most reliable and ruggedized ways is to encapsulate or seal the electronics in a potting material.

The simplest example of potting electronics is to place assembled electronics in a case of some kind. Potting materials are then poured around the electronics and allowed to cure, creating reliable protection.

There are many different types of products used for electrical potting. Some of the most popular are Epoxies, Urethanes, and Silicones. These products represent three versions of thermo-setting chemistries and are typically supplied in two-component forms, and mixed and poured on site. Table 1 below graphically displays a comparison between epoxies, urethanes and silicones across typical characteristics.

Property	Epoxy	Urethane	Silicone
ADHESION	Best	Better	Poor
PHYSICAL STRENGTH	Best	Better	Poor
ELASTOMERIC/RE-ENT	Poor	Better	Best
ABRASION RESIST	Better	Best	Poor
HIGH OPERATING TEMP	Better	Poor	Best
LOW OPERATING TEMP	Poor	Better	Best
CHEMICAL RESISTANCE	Best	Better	Poor
EXOTHERM	High	Low to Medium	Low
COST	Medium	Low to Medium	High

Epoxy products typically give excellent adhesion, physical strength and chemical resistance and are very hard. They can be formulated to resist high operating temperatures and can be supplied at very competitive costs. However, if care is not taken during formulation, epoxies can be very brittle and prone to cracking.

Urethane products are typically softer in durometer, which can make them advantageous for protecting more sensitive components. They can excel at lower temperatures. Additionally, urethanes can typically be formulated and manufactured at a competitive price. Urethanes are naturally very moisture sensitive, and great care must be taken to protect them from moisture contamination, especially humidity.

Silicone products typically range from very soft gels to the hardness of a car tire. They can be used across a wide range of operating temperatures from very low (<-40C) to very high (>200C). However, silicones offer poor adhesion and come with a higher price tag.

Thermal Management

Thermal management of electrical components is becoming more and more important as designers and engineers seek to achieve greater capability through smaller designs. Using a thermally conductive potting material to help move this heat out of the part is a popular choice. In potting compounds there are a few typical ways to increase thermal conductivity, but they also come at a cost.

The thermal conductivity of a typical unfilled epoxy or urethane system is approximately 0.3 w/mK. In order to increase the thermal conductivity, mineral fillers must be used. By increasing the filler load to a certain point, you can also increase the thermal conductivity of the material. However, the amount and type of filler also increases two properties: abrasiveness and viscosity.

By adding any mineral filler to a potting material, the viscosity can be greatly increased. Viscosity is a measurement of the rheology of a material, or how easily it flows. The higher the viscosity, the slower and more difficult it is for a material to flow. By increasing the viscosity, the material becomes more difficult to pour, which in turn also makes it more likely to trap air.

Certain mineral fillers, such as alumina oxide, can yield a much higher thermal conductivity than softer mineral fillers. However, alumina oxide in particular is extremely abrasive. Normal use of a highly filled potting material with alumina oxide will also require more durable machinery and a higher rate of preventative maintenance on the dispensing equipment.

Users of highly thermally conductive materials also take advantage of epoxy and urethanes ability to reduce viscosity when heating the material. Typical highly filled epoxy systems can be processed at a higher temperature, reducing their viscosity, and increasing flow and air release.

Cured Performance Characteristics

How a cured material performs across a range of temperatures can be critical to the long-term performance of the material they are encapsulating. All materials expand and contract across different temperatures. It is critical to consider both the hardness and the Coefficient of Thermal Expansion (CTE) when considering different potting materials.

When potting very sensitive components that will experience harsh thermal cycling environments, a common choice is to use a very soft, or low durometer, material. As the part and potting material cycle through temperature extremes, the softer potting material will simply deform, absorbing the expansion and contraction of the other components. With greater and greater density of sensitive components, this approach continues to grow in popularity and use.

Another choice is to use high hardness potting materials with very low CTE's. By attempting to match the CTE of the potting material with the parts being potted as closely as possible, the entire assembly will expand and contract in unison. In order to achieve the low CTE desired, it is critical to add a high level of mineral filler to the potting material as well. This both increases the thermal conductivity of the system and decreases it's processability,

Glass transition temperature (Tg) can also impact a potting material's CTE. The Tg of a product is the temperature at which the material goes through a phase change, from a glassier, rigid material, to a softer, flexible material. Urethanes and silicones can have very low (-40C) Tgs. Epoxies can have very high Tgs (>200C). Typically, a material will have a lower CTE when below the Tg, as the material is in a rigid, glassy state. Above the Tg, the CTE is typically greater when it is in its flexible, softer state. The benefit of operating above a materials Tg is that you can be sure the material will remain soft and compliant throughout the operating temperature of the end device. High Tg materials are often chosen for high temperature applications where excellent adhesion and strength are required, or to ensure a very low CTE. This will ensure the polymer will expand and contract at a rate similar to that of the components and/or substrate.

The Processing Problem

Since most potting materials are supplied in liquid, two components forms, they must be mixed accurately and poured on site. Most major users of potting materials use a form of automated or semi-automated machinery to improve the consistency of the finished product. In many cases, designing a process to mix and pour two-component potting materials can be as complicated as formulating the potting material itself. Most processing lines have three distinct sections:

1. pre-conditioning and handling the material
2. metering, mixing, and dispensing the material
3. curing the material.

Some materials may require pre-conditioning and handling before being processed. Typically, epoxies and urethanes may be heated to reduce viscosity, agitated to prevent filler settling, nitrogen blanketed to protect from moisture contamination, and vacuumed to remove trapped air. Proper selection of holding tanks and transfer mechanisms is critical to ensure that pre-conditioning the material does not alter its final cured performance.

The heart of the processing equipment is the meter mix dispense machine. This is the equipment that ensures the material is mixed on ratio, and mixed completely. Without complete, on ratio mixing, the two component systems will not cure correctly, and could result in failures, poor performance, or simply not curing at all. A good machine will offer the ability to consistently deliver properly mixed material over a long period of time with limited waste.

Vacuum chambers may be utilized to prevent the occurrence of trapped air in a finished part. Many machines are designed with vacuum chambers as part of their process.
The final stage of processing is the cure. Certain potting materials may require specific parameters to ensure proper cure. The most typical is curing under heat. Parts may be exposed to heat on an automated line as it is transferred through an oven, may be placed inside a separate oven, or sometimes cured on a hot plate.

Poor selection or design of processing equipment can lead to long-term manufacturing problems, quality issues, field failures, scrap costs, down time and other issues. It is critical to ensure that a processing solution is chosen that matches both the potting material and finished part.

Conclusion

We live in an exciting time of rapid change in how electronics and electronic technology is designed and used. As we continue to pursue advanced technologies, we must also consider how to protect those technologies from the environment to ensure long-term operation. Proper selection of potting materials can be critical in determining if an electrical component lasts for months or years. The topics covered in this white paper are simple explanation of the concepts used by potting material manufacturers to design, select and formulate products. A thorough understanding of these concepts can yield great savings in time, operational expense, and reduced waste. While considering different potting materials, it may also be advantageous to seek out custom formulations that can be designed for specific products and manufacturing lines.