TeligentEMS

The Reliability Equation:

Secondary Processes That Help Ensure More Robust Product

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It is relatively easy to design an electronic product to achieve desired reliability over its planned usable life when the product will be kept stationary in a room temperature operating environment with no exposure to the elements, shock or vibration. It is much harder to do that when the product will be exposed to water, salt spray, extreme temperatures, high humidity, sand, corrosive gases, vibration, extreme g-forces, shock or outer space. In these cases, electronic interconnections and sensitive components must be protected from conditions that could weaken solder joints or components themselves through corrosion or excessive stress on the interconnection. Coatings, bonding, potting, and encapsulation offer the best option for providing that protection. However, the type of material selected is highly dependent upon desired cost and application.

TeligentEMS, an EMS provider headquartered in Havana, FL, has significant experience in manufacturing mission critical products utilized in harsh environments which require secondary coating, bonding, potting or encapsulation processes. This whitepaper looks at the benefits and tradeoffs associated these secondary processes.

Conformal Coating

Conformal coating offers the least expensive option for protection but isn't as robust as potting or encapsulation options. There are four main types of conformal coating material: acrylic, silicone, urethane and parylene. The best coating for the product is determined by analysis of the operating environment.

Typically conformal coating is either applied manually in a spray booth or automatically via a machine which follows a preprogrammed spray pattern. There are benefits and disadvantages to both methods in terms of flexibility and setup time.

Acrylic conformal coating is typically the lowest cost, easiest to apply and easiest to rework, but it doesn't protect in corrosive environments such as salt spray. Silicone performs better in high heat (up to 200 degree C) applications. Silicone is also more resistant to chemicals, making it a better choice for protection when chemical fumes or contact are present in the operating environment. It also holds viscosity better, making it the preferred choice for thicker applications because it can build up to the desired level with fewer passes than acrylic coatings. The challenge with silicone is that it must be removed with solvents which can damage components. Silicone must also be applied within an enclosed area of the factory because of its fumes and potential to contaminate other products if even small amounts vent into the production area. Both coatings provide sufficient protection from mold, fungus, moisture and dirt.

Urethane is typically used when the operating environment includes humidity and/or salt spray. Parylene represents the most robust option, but it is also the most expensive option because of the specialized equipment used in its applications. It is typically used on products in air frames or space.

One key design consideration with conformal coating is connector selection. When either an automated or manual conformal coating process is used, soldered terminals on the back side of connectors can be inadvertently sprayed if open structure types are used. This allows wicking of conformal coating inside the mating areas. If a connector which has covered or sealed back side is selected, the spray will not interfere with mating areas. Another design consideration can be component layout. Not all parts can be conformal coated and those parts are often masked off prior to process. Most design considerations for coating involve points of egress for testing and critical connections. It is also important to consider masking and de-mask strategy. The more efficient the layout in terms of segregating these non-coated parts, the less masking time is required.

If a design team wants many test points on the PCBA, pads are left exposed. However, the greater the number of cutouts on the board the weaker the bond and the higher the masking charge. It is better to design a functional test that is done prior to coating or design a test initiated through a connector after the conformal coating process.

Because conformal coating and any concomitant masking does drive extra cost, it can be important to discuss whether or not the conformal coating process is truly needed and also whether or not design choices relevant in the development stage are equally relevant in production.

For example, in one military application, the design team specified 39 test points. When they received the masking quote, they decided to re-evaluate the product to lower the masking cost. It turned out several of the test points were only needed during development and did not need to be used in production. Similarly, some design engineers order every product coated, just as a standard practice to ensure safety. If the PCBA is going in a sealed box, coating may be unnecessary.

It is also valuable to do a mechanical review of the PCBA in its subassembly to ensure that the coating will not be mechanically abraded in the operating environment. Options in the event an abrasion risk exists, include utilizing a more robust coating or changing the design to eliminate the issue. In existing product, a spike in end-of-life failures can be an indication that a coating is being abraded and correcting that should be a priority in redesign efforts.

One other area where conformal coatings are starting to provide a benefit is tin whisker mitigation. Coatings are normally one step in a two-or-three step tin whisker mitigation program for long lifecycle products. While aerospace and military products are still exempted from RoHS regulations, the supply chain has eliminated many tin/lead component options. As a result, companies taking the RoHS exemption often still have to adjust their processes to reduce the risk of tin whiskers. One option is changing the alloy composition to get a minimum of 3% lead in the solder joint. The component may also be resurfaced to change the finish from tin to tin/lead to ENIG finish. Coating the printed circuit assembly (PCBA) with acrylic usually limits the tin whisker growth to three dimensions. Using urethane can limit tin whisker growth to two dimensions.

Component Bonding

Component bonding, also known as staking or ruggedization involves the application of adhesives during the assembly process. Adhesives vary in rigidity and hardness. The harder a cured adhesive becomes, the more likely a sharp force can break it. Consequently, products likely to be subjected to sharp impacts should use more flexible adhesives if this choice is considered.

Potting and Encapsulation

Potting is predominately used for products in operating environments where the product is likely to be exposed to vibration or severe chemicals, such as petrochemicals. The part of the product to be potted is immersed in a potting compound, which hardens once cured. The main disadvantage of potting is that it is not usually possible to rework potted product.

A key design consideration is that components which protrude from the potting compound must have relatively close coefficient of thermal expansion (CTE) characteristics. The materials must also be aligned enough to promote adhesion or it is necessary to use an adhesion promoter to avoid mechanical separation. When the operating environment is benign from a thermal perspective, but involves exposure to harsh chemicals, veracity of the material becomes the most critical factor in material selection. Polymeric cross-linked material which has a repeating polymer structure addresses veracity concerns because it is more chemically resistant and more difficult to break down. Good examples of commonly used polymeric cross-linked materials are FR4, polymide and Teflon.

Encapsulation is a form of potting that is used when specific components must be protected with an underfill. It is also an option for tin whisker mitigation.

In the encapsulation process, the PCBA is cleaned and the area containing the component to be underfilled is heated. Once the desired temperature is achieved, the PCBA is removed from the heat and the underfill material is applied in an L pattern on two sides of the component. Capillary action wicks it under the component and the PCBA is cured. X-ray inspection is used to check for voiding. Voids on the edge of the component can be manually touched up. However, if the number of internal voids exceeds the allowable number, it may be necessary to start the process over. Not all underfills are reworkable, so there can be high scrap rates with this process. It is typically used when the operating environment includes extreme vibration.

When encapsulation is used, designers need to consider how the area will be segregated. The potting process often requires a mold to hold the potting material. If the mold must be removed, that adds cost. A less costly option may be a washable mechanical containment tray. In some cases, the containment tray becomes part of the mechanical integrity of the product.

Both potting and encapsulation may be used for cryptographic purposes, when the original equipment manufacturer (OEM) wants to protect the design from intellectual property theft. Both processes keep the components that are potted or encapsulated hidden and it destroys the components if there is an attempt to remove the potting or encapsulation material.

A disadvantage is that potting and encapsulation limits rework options and makes failure analysis problematic because the post-potting condition can't be fully analyzed. It can create issues in manufacturing because if a product tests good pre-potting and then fails after potting, the defect may be a bad component or material mismatch.

Environmental Considerations

From an environmental perspective the most difficult to use materials have been eliminated. Today, the biggest issue is materials with volatile organic compounds (VOCs) which require use of a hood for venting or a breathing mask during application. In terms of disposal, the best practice is to cure material prior to disposal.

Use of coating, bonding, potting or encapsulation can help prevent field failures in harsh environments. Each process has advantages and tradeoffs. Material selection is highly dependent on operating environment. And, each of these processes add cost. Working with a contract manufacturer experienced in these secondary processes minimizes the design learning curve and can help in rapid identification of the best material and process at minimal added cost.

About TeligentEMS

For more than 30 years, TeligentEMS has provided a full range of electronic manufacturing services to companies in the industrial, medical, military/aerospace, telecommunications and instrumentation industries. We specialize in technically complex printed circuit board assemblies, subassemblies and box build. Our superior RF expertise enables us to support a wide range of communication technologies. We are ITAR registered and ISO 9001 and ISO 13485 certified.

Our global procurement and supply chain capabilities, combined with our real-time systems for project status, quality data collection and device history recordkeeping ensure we offer customers a cost effective and highly responsive solution.