With the advent of such concepts as “smaller, faster, and cheaper” in electronic manufacturing, the need for decreased component size, narrower lead spacing, and higher frequency devices has emerged. Unlike through-hole technology, which allowed for inches of spacing between leads, a simple enclosure or box to protect packaging devices and circuit boards is no longer a viable option. The required performance of these electronic devices in many different types of operating environments has led many package device fabricators and PCB assemblers into the world of conformal coatings.

Due to the havoc caused by moisture and condensation in the environment, many devices and surface mount and fine-pitch PCB components could not operate without the use of a conformal coating or some type of encapsulation. Conformal coatings provide a thin dielectric and protective moisture barrier to the device leads and other conductors on the board. As many assemblers build devices directly onto the circuit board via flip chip, chip-on-board, or direct-chip-attach, there is little difference in the use of conformal coatings between SMT and other packaging technologies.

Conformal coatings are available in a large variety of chemistries, including silicones (SR), acrylics (AR), urethanes (UR), epoxies (ER), parylene (XY), and fluorocarbon (FC). Most of these are available as traditional, solvent-based materials or newer, solvent-free formulations. Adding to the challenge of choosing a conformal coating is the wide range of curing chemistries employed into these materials, which include room-temperature, heat, UV, and cationic cures.

Deciding which type of chemistry to use depends on factors such as end-use environment, temperature range, type of components on the board, and rework procedures. The cure mechanism depends on the cycle time of the production process; how soon subsequent testing is performed; and the volumes and cycle times of the devices and boards to be coated.

Adhesion is one of the most important features for any coating material. Without adequate adhesion, moisture molecules can pass through the cured coating and deposit on the substrate, causing a variety of potential problems such as dendrite formation, corrosion, and electrical failure.

Existing specifications governing conformal coatings only test the coating material on a bare FR4 or G10, which looks only at the coating material without other variables. Actual results of a coating’s performance will usually depend on the type of soldermask, flux residue, and cleaning solutions used on the assembly prior to conformal coating. With so many choices and configurations available, the assembler should test the performance of a candidate coating material on his actual assembly (IPC-CC-830B). Providing the adhesion of the coating is adequate; any
condensation or moisture which accumulates on the assembly should not penetrate to the surface interface, and will provide a sound layer of moisture and dielectric protection.

Most package device fabricators and PCB assemblers prefer to use solvent-free chemistry for economical and environmental reasons, but solvent-based materials enhance performance with adhesion and increased resistance to mechanical abrasion. However, evaporation of solvent equates to waste, potentially increases VOC emissions, and can pose health and safety issues. Luckily, many of the traditional chemistries are available in solvent-free formulations and use VOC-exempt solvents, with little or no impact on cure speed, performance, or the environment. Recently commercialized “controlled volatility” silicone conformal coating materials, which have much lower volatiles, can be used directly on open-die and internal to the device package. Flip chip and any chip-on-board technology can benefit from these new materials. Because the silicones are soft elastomers, they do not stress the fine-wire die leads, leaving the die enroute to the interposer.

Softer, more flexible coatings are gaining in popularity due to the small size of the component leads and the potential for CTE mismatches, which can exert enough force during cycling to shear or fracture the leads or break glass diodes. Any place on the device or board where a wire bond or vertical lead leaves the substrate, capillary action can cause a coating “fillet” to form. These fillets can be greater than 20 mils thick, so a hard or brittle material can be mechanically disastrous, especially on fine-pitch assemblies or assemblies that must endure high levels of thermal cycling and vibration.

Application methods have also changed dramatically. Until recently, dip, spray, and brush were the only choices. Now, several automated application systems are available, including robotic application systems that can be programmed to coat the assembly only in prescribed areas. This can reduce most of the masking and de-masking operations typically associated with the conformal-coating process, thus eliminating the need for “batch” or “off-line” activities. The entire coating application process, including any in-line cure step, can be done in-line.

Understanding which chemistry, cure method, and process or machine would be best suited for a particular coating application can be a confusing and time-consuming exercise for engineers not fully versed in the technology. Industry documents, such as IPC-830 HDBK, are new tools that explain the benefits and drawbacks of each chemistry, application method, and cure mechanism. Involve the material suppliers and the equipment vendors early on in the project to save time and reduce a multitude of problems regarding the many choices available. It also helps to identify and understand in what end-use environment the electronic assembly will perform; whether one or two sides will need coating; what the volumes are; how much coating will be required; and what the cycle times are.

Understanding what materials will be coated is paramount to reliability and conformal coating success. Is there good adhesion to the soldermask and solder sites? How much flux residue will reside on the device or assembly at time of coating? Are the assemblies within the limits set for ionic contamination? Does the coating material wet-out well on all the substrates? Is adhesion adequate after thermal and environmental cycling? Answers to these basic questions, along with any potential need to rework, will lead board assemblers to the best candidate coating materials for their specific application.

Whatever left-over process residue remaining on the device package or board will still be present after the coating is applied and cured. High ionic content and high levels of un-volatized flux can cause problems at the outset. If ionic contamination is too high, everything required to cause a corrosion cell will be present with the exception of water. A soldermask that has not been completely cured can also contribute to premature corrosion, electro-chemical migration (ECM), and dendrite formation. Many component mold-release agents and legend markings can also cause a conformal coating to de-wet or “orange-peel.”

The IPC recommends cleaning electronic assemblies prior to conformal coating. If the boards are being cleaned, consider the cleaning agents being used and any residuals they leave behind. Also consider how “dry” the assembly is prior to coating, especially if employing an aqueous cleaning technology.

Lead-free solder also affects the conformal coating operation. Low-lead alloys reflow at much higher temperatures than eutectic solders, causing any absorbed process residues to leach out from the substrates, components, and interconnects. Process “garbage” never-before-seen may loom at the surface. It is these types of residues that the chosen candidate coating material will have to adhere to and co-exist with.

Conclusion

The design of a conformal-coating process must answer all of these questions to be economical, efficient, and successful. Only once this is understood can the process be reliable and totally foolproof.

Some material suppliers have programs available to help design, prototype, test, and install the entire coating process for customers who do not have the internal resources or in-house expertise to do it themselves with a great deal of confidence. Some of these solutions’ proposals include all the candidate testing, process documentation, rework procedures, QA, and equipment, depending on customer needs. In some cases, equipment costs can be rolled into the material cost over a period of time, making a capital investment less painful for available cash flow.

*AR chemistries dry via solvent evaporation. They do not truly “cure.” Parylene is applied in a chemical vapor deposition process and deposits in the cured state.

Photo courtesy of Asymtek.

References


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