

Conformal Coating for Microelectronics: A Primer

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The conformal coating of an electronic assembly is not often considered by designers at the beginning of a project. Until recently, this operation was equated with massive manual masking prior to spraying or dip coating, rather than a selective, precise process. Because conformal coating is often mistakenly thought of as an added cost rather than an added value, it is seldom considered during the board design phase. As a result, the decision to use conformal coating usually occurs when field testing reveals its need.

Many original equipment manufacturers (OEMs) and electronic manufacturing services (EMS) companies will have to adopt automated and precision conformal coating processes to improve consistency and quality of their products. The competitive marketplace also is a driver for automated conformal coating because it can result in faster process times, reduced rework, easy handling, and other such factors. There are a number of steps that can be taken to ease this transition. They will help the process owner avoid common mistakes, oversights, and unnecessary pain, be it in the pocketbook or the process itself.

Product Considerations

The first thing to look at is the product itself to determine its field performance demands. These include environmental demands, product geometry, and coating requirements. The combination of the elements the product will be exposed to, such as vibration, temperature extremes, humidity, and chemical resistance, will determine the kind of protection best suited to withstand that exposure.

Product geometry is a factor because some substrates may be perfect from the electrical functionality point of view, but can present tough challenges for the selective coating operation. Not paying attention to this may result in a poorly suited equipment application, slowed down process, or high rework rate, resulting in unexpected associated costs.

Product geometry includes overall dimensions (length, width, height), edge clearance, required top and bottom clearance, weight, whether it's a one or two-sided application, and whether the loading method is batch or conveyor. If using a conveyor, another consideration is whether the product is being loaded individually or on a pallet.

If the product needs to be repairable, will the coating and process selected allow repairability during the process and/or after use?

Material Considerations

The coating material will be determined primarily by the product performance needs, then by factors such as ease of application, cost, and handling. Typical coating materials are acrylic (AR), urethane (UR), silicone (SR), and epoxy (ER). They are also classified by cure method as heat cure,

UV cure, or moisture cure. As mentioned above, consideration of whether the coated part can be reworked or repaired using that material is another factor.

How the material has to be handled can be critical because it might require special equipment to maintain the material at a consistent temperature or viscosity to dispense it correctly. Some materials will require mixing to have a desired solid content prior to the application. Either a mixing station is necessary or in some instances the material supplier can provide a pre-mixed product. The material's pot life will determine the production level that can be achieved before the fluid reservoir has to be changed; the amount of material to be prepared will also depend on the pot life.

The way a conformal coating material is packaged can make a difference because exposure to ambient conditions can affect certain materials. Mechanisms used to enhance the performance of materials can also make these materials sensitive to light sources or ambient moisture, causing acceleration of the cure rate or decreased pot life if not properly handled. Safety is another factor as there are materials that may require particular care when handling, such as the need to maintain in a ventilated area, use gloves and respirators, and to keep away from ignition sources.

Process Considerations

Process considerations include the type of operation, production volume, application method, automation requirements, takt time, and ancillary equipment. The type of operation determines if the required production can be achieved in a normal eight hour day, five day work week shift. If the projected needs require more than what can be accomplished in two shifts, it might pay to invest in equipment with a higher production rate. A rule of thumb often used is

Batch <50 parts/8 hr. shift

In-line >50 parts/8 hr. shift

The production volume required is a good place to start in selecting equipment and determining the type of operation required, but other less subtle factors for increasing production should be considered. One such factor is the application method. Equipment that selectively coats parts can save considerable amounts of time by eliminating the need for masking/de-masking operations. Time and money is saved by reducing multiple coating passes, being able to adjust the coating speed, and using equipment that can be easily programmed and that is flexible enough to adapt to program changes or modifications.

There are several types of coating applicators:

Spray coating is an atomized process that can achieve a thinner film pass; however, if selectivity needs to be achieved under this process, the applicator usually has to move more slowly. The finish is a feathered or fuzzy coating on the edges.

Curtain, or flow coating, can maintain high application speeds, produce sharp edges, and provide a film build of 25 to 75 micrometers (1 to 3 mils); therefore, if suitable for the application, it has the advantages of fast process time, selective coating, and good film thickness. It also meets the need for consistent application, reduced masking and unmasking, and a one-pass application to reach the appropriate film builds, all factors that increase speed of the operation and reduce costs.

Using a needle to apply the coating has always been the default choice for small areas and semi-controlled flow. It works well for discrete areas where it is okay for the needle to touch or get very

close to the substrate to initiate material flow through capillary effect. Because it can slow down the process, it is sometimes combined with a second, faster applicator that can also be appropriate for discrete, small area dispensing.

The jet is relatively a newcomer to conformal coating. It has many advantages for selective coating of small parts, especially when coating needs to be applied in hard to reach spaces. The jet can shoot small volumes of material without touching the substrate or concern for substrate warpage. It is faster than a needle because the material is shot out, eliminating the up and down motion. The combination of speed, selectivity, and precision provides advantages for these new conformal coating applications that no other tool has achieved.

Automation results in many process control advantages that just aren't possible with a manual or semi-automatic process. They provide an additional level of control when trying to ensure quality. New ways to refine the automation processes are being made available with the added benefit of bringing controls and settings into the programmable coating application. Below are some of options that are available:

Flow monitoring measures and maintains volume flow within certain programmable upper and lower limit levels. An out-of-limits alarm notifies the user if the process moves beyond them.

Viscosity control is extremely important in the conformal coating process to coat parts evenly, because constant viscosity results in uniform thickness deposition and a consistent application pattern. Viscosity and coating patterns can change as temperature changes. The ambient temperature on a manufacturing floor can fluctuate up to 10°C during a manufacturing shift, so a process control that maintains a constant temperature in the coating eliminates one more variable.

Pattern width control, which is also called laser fan width, automatically verifies and adjusts the fan, or coating pass, width as needed. It is also beneficial to achieve tight keep out areas.

Closed-loop control of key parameters such as fluid pressure and atomizing air pressures can be set-up as part of a standard coating recipe.

Event logging is becoming more important for traceability. Multiple parameters are recorded for analysis using external SPC applications or for interaction with special protocols related to Factory Information Systems, where, through an ID method like a bar-code reader, a process executed on a product can be traced and attached, together with their application parameters.

Takt time = cycle rate = drop rate. The term takt time refers to the amount of time it takes to load, execute a coating operation, and unload. It's used as a measure of production capability, to determine the bottlenecks and the number of machines required to fulfill a determined production rate.

Ancillary equipment depends upon what the process demands are. The need for this equipment is based on what the cycle rate is and how the process is set. Examples of ancillary equipment are material handling and cure equipment. Material handling equipment consists of conveyor lengths, in-line inverters, stackers, or product accumulators. These are typical of in-line systems and are necessary to maintain the speed of the process and minimize operator intervention, thus driving up the production rate.

Cure equipment is chosen as a function of material and process speed. The most common cure equipment used are heat cure and UV cure ovens. A heat cure oven consists of a conveyor inside a heated chamber of a given length, which is calculated according to the required cure time and the cycle rate. It's usually at the end of the line and the only additional equipment that follows it is either an open conveyor or a product accumulator. A UV cure oven also consists of a cure chamber, but is very short because UV cure processes occur in seconds; therefore, they are often used for high production rates.

Inspection stations are usually considered in two instances: touch-up or quality assurance. They have different needs such as open access, extra ventilation, or small tool holders, or just an inspection light to verify coverage. There are multiple combinations of these, but it should suffice to mention that they are available and customization is often possible.

Economic Considerations

The cost of conformal coating must be weighed against the costs of not protecting the electronic components. One thing to consider is the replacement cost of the components if they fail due to factors that could have been prevented by conformal coating. When the life of a product is increased, the cost of returns will decrease.

Another consideration is the cost of the coating method. Dip coating will greatly increase material usage and cost. Spray booths may use less material than dip coating, but the total process cost is higher because the number of operators and operator time is greatly increased due to the need for masking. Automated selective coating may have a high initial cost, but the total cost of ownership will be low due to the decrease in material usage, the reduced cost of the operations, and the reduced return rate of the product.

Summary

Conformal coating started as a simple process performed on electronic substrates in need of extra protection from external elements with little attention paid to quality factors, other than ensuring adequate coverage of the components. The increased capability of semiconductor assemblies to perform more complex tasks in automotive applications, traffic control, signage, outdoor surveillance, and for mission critical elements has increased the demand for conformal coating to protect these devices. Because failure of these devices could have dire consequences, the quality of the application of the coating materials is critical. New equipment and processes are in place to accommodate the conformal coating requirements of these emerging technologies. A smooth transition to automated precision conformal coating can be achieved through an analysis of the product being coated and the desired result, the coating material used, the process selected, and an evaluation of the economic costs over a period of time.