Utility of Dual Applicators for Non-Atomized Conformal Coating to Improve High-Volume Manufacturing Optimization

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Abstract

Electronics manufacturers protect their circuit boards with conformal coatings. Conformal coatings serve as a barrier from environmental hazards and internal shorts, tin whiskers, and corrosion at the board level. Within conformal coatings different material chemistries specialize in shielding from an array of hazards and can be applied by multiple methods. The most common method is atomized spray which disperses the material into a fine mist. Alternatively, non-atomized coating controls the materials' dispense shape while maintaining the original liquid form. While some applications demand atomized spray and other scenarios overlap between atomized and non-atomized coating, this paper focuses on the circumstances where materials are ideally suited for non-atomized, selective coating.

Board manufacturers and their process engineers are tasked with effectively protecting the boards they produce. High-volume manufacturing recognizes optimized set-ups to improve dispense quality, process control, reliability, and repeatability, while reducing material costs. For high quality, accurate, and repeatable conformal coating with efficient throughput, large-scale manufacturers utilize automated selective coating. Selective coating is used to coat specific components or areas of a board while respecting keep out zones. To further increase transfer efficiency, selectivity, throughput, yield, and reduce masking and rework, a non-atomized process is worth consideration.

At times the best way to achieve target results requires an effective team. This can be accomplished using two applicators with different dispense technologies. The first is a film coating applicator with a non-atomized dispense that delivers a clean edge definition and coats boards with broad passes up to 750mm/sec. This applicator can be paired with a precision jet applicator that has capability for dispensing discrete dots. This resulting combination enables high-volume manufacturers to create conformal coating programs to maximize control, reduce waste, increase throughput, selectively coat, and reduce rework. Adding process controls to an automated system provides accountability with traceability and process parameter maintenance. By pairing these two applicators the utility for non-atomized, selective systems will continue to grow.

Key Terms: Conformal coating, film coating, non-atomized, edge definition, jetting, wet accuracy, mechanical accuracy, repeatability, transfer efficiency, overspray

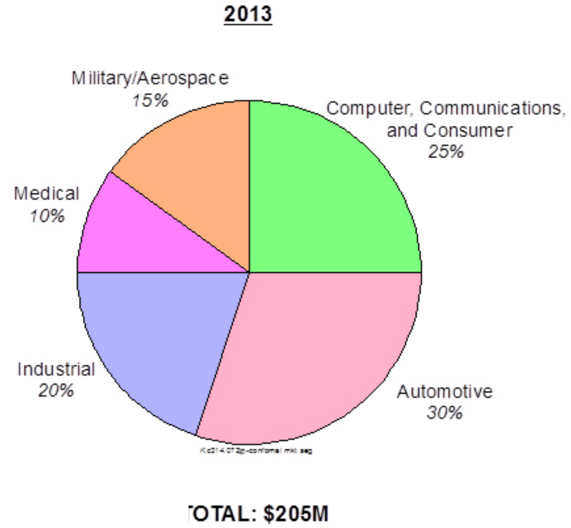
Market Overview

Conformal coatings provide a protective barrier on circuit boards. Electronics manufacturers aim to defend their circuit boards from environmental hazards and internal shorts, tin whiskers, and corrosion at the board level. Various coating chemistries specialize in shielding from an array of hazards and can be applied by multiple methods. The majority of conformal coating focuses on computer, communications, and consumers and automotive manufacturing. As shown in Figure 1, these industries make up more than half of the market segment and require high-volume manufacturing.

The materials used are largely solvent based, as summarized in Figure 2. Solvent- based materials are typically acrylic and urethanes, whereas 100% solid materials are comprised of silicones and other urethanes. The large consumption of solvent-based materials is illustrated in the 47% by volume for acrylic materials and some portion of the urethane volume. Compared to 100% solid materials, solvent-based materials have more customized viscosities depending on the mix ratio of material to solvent. The ability to achieve a low viscosity (50-150 cPs) range with solvent-based materials allows for a specific non-atomized technique, film coat technology. In film coating, a curtain of material is applied instead of the atomized spray that disperses the material into a fine mist. The curtain of material produces a clean edge as opposed to traditional air spray where the edge is undefined and overspray is a concern. Furthermore, the use of added solvents facilitates optimizing viscosity for the process and can help counteract production issues such as bubbles and orange peel.

Table 1 shows the properties and chemistries of conformal coating materials.

Figure 1. Conformal Coating End Market Segments 2013. Courtesy of Prismark Partners, LLC.



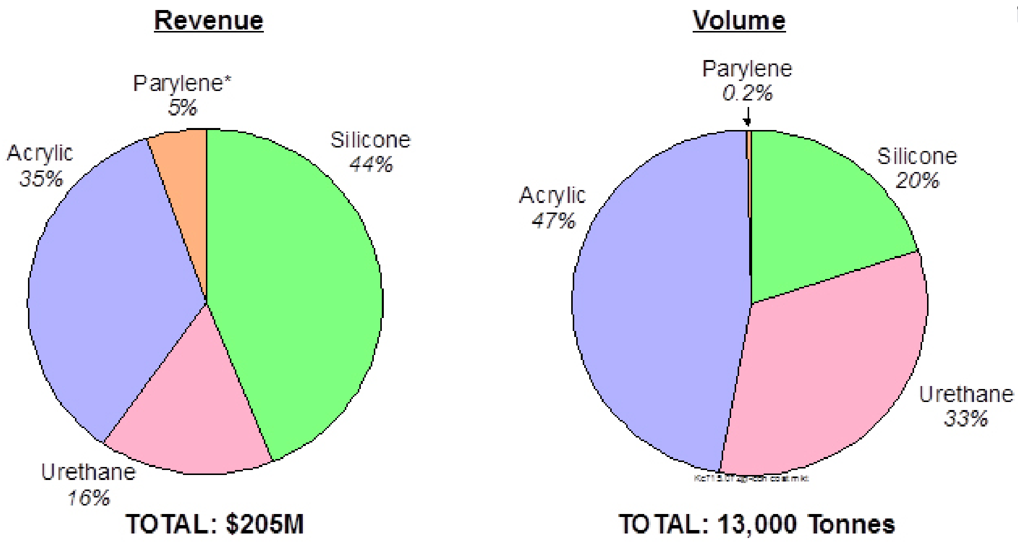


Figure 2. Conformal Coating Materials 2013. Courtesy of Prismark Partners, LLC.

Table 1. Conformal Coating Chemistry and Property Summary

Material Type	Reparability	Moisture Protection	Abrasion Resistance	Solvent/ Chemical Resistance	Mechanical Strength	Flexibility
AR Acrylic	Good	Good	Good	Poor	Fair	Fair
UR Urethane	Poor	Good	Good	Good	Good	Good
SR Silicone	Fair	Fair	Poor	Good	Poor	Good
ER Epoxy	Very Difficult	Good	Good	Good	Good	Poor

Applicator Types, Benefits and Limitations

Spray Benefits and Limitations

Atomized spray is a popular technique in the electronics manufacturing industry for many reasons. Spray applicators have a wide range of viscosity acceptance. The incorporation of 100% solid materials includes coatings with lower volatile organic chemicals which evaporate and are hazardous to operator health.

Spray coating has advantages with 3-dimensional coverage. The fine spray particles adhere better to the varied board topography without fluid flow or pooling. The material stays where it is applied.

For all of the benefits, spray coating also has limitations. Due to the dispersion of material, a single pass has a feathered edge because the mist particles extend the edge definition and detract from a clean line, as captured in Figure 3. Because particles travel, an atomized dispense is prone to overspray.

Overspray, which is material dispensed beyond the required area, results in either waste or contaminating Keep Out Zones. The typical approach to this problem is masking. Masking requires significant additional labor cost as operators must prepare and remove the mask around the coating area. Costs also include the actual masking material itself, whether it is tape, a fixture, or a cover. Additionally there is risk of damaging the coating with operator intervention during mask removal. Furthermore, when dealing with solvent-based materials, atomized spray can cause cob-webbing, a phenomenon where the material dries before adhering to the board. The drying leaves a polymer chain that will float until it finds a landing surface, either on the board or around the machine. Cob-webbing wastes material, dirties the machine, and contaminates the board.

Figure 3. Atomized spray coater.
Applicator tip with spray pattern (left), top view of spray pattern (right).

Non-Atomized Spray Benefits and Limitations

In order to improve transfer efficiency, selectivity, and throughput, a non-atomized process may be the best solution for solvent-based materials. Non-atomized dispensing methods include film coating, needle dispensing, and jetting. The various methods mold the fluid shape to obtain selectivity, clean edge definition, and at different dispense volumes. All of these methods provide the user a higher wet dispense accuracy without overspray.

A film coat pattern dispenses material in two distinct shapes. The primary shape is a leaf pattern that dispenses a curtain of material as the applicator moves; at the perpendicular angle, the dispense pattern is a knife edge. Figure 4 demonstrates the pattern and dispense shape. The shape allows for broad, wide passes to place significant quantities of material. A needle dispense primarily uses fluid reservoir pressure to push material through a needle to dispense a narrow bead. The jet applicator has the finest volume control by dispensing discrete dots. Lines are comprised of a series of dots that blend together and by controlling the volume of a single dot, the system controls the volume of material dispensed across lines and coating patterns. While all of these tools are considered selective on their own, complex boards may benefit from a combination of these applicators to maintain selectivity and increase flexibility.

Film or Curtain Coater Benefits and Limitations

The film coater utilizes a cross-cut nozzle to establish the fan dispense shape. When dispensing with a film coater, the shaped edge sets the pass edge on the substrate. Dispense pass width can range from 3-15mm though typical dispense passes are ~10-12mm wide. Its wide pass is ideal for low-profile, surface mount populated boards. With low components, the applicator can sweep across the board at speeds up to 750mm/sec.

Typical cured thicknesses for solvent-based acrylics and urethanes are 25-75um (1-3mils) in a single pass. Thickness is specified by IPC standards and can be controlled by hardware, line speed, and viscosity. The solvent-based material can have more or less solvent added to create a desired thickness.

The film coater does have a few restrictions. The applicator is limited to solvent-based materials with an optimized viscosity. The film coater also dispenses large volumes of material; at a low viscosity, the material may pool around leads and other components, thinning coverage in other areas. The movement of the fluid flow is subject to the material properties and the surface tension of the board. Due to the applicator's physical size, access around tall components is limited. Furthermore, tall components can obstruct the dispense fan, requiring additional passes for complete coverage.

Applicators to Pair with Non-Atomized Applicators

Different types of applicators can be paired with the non-atomized coaters to realize the full benefit of dual applicators in high-volume electronics manufacturing. The most popular are needle and jet applicators.

Needle applicators have a wider viscosity range than the film coater and can be used for complementary applications. The needle dispenses a bead of material as a simple time-pressure applicator, captured in Figure 5. The uniform, narrower pattern shape allows for contouring patterns, like circles or sharp 90-degree angles. Using a continuous path program routine can seamlessly smooth contour lines into a clean perimeter dispense.

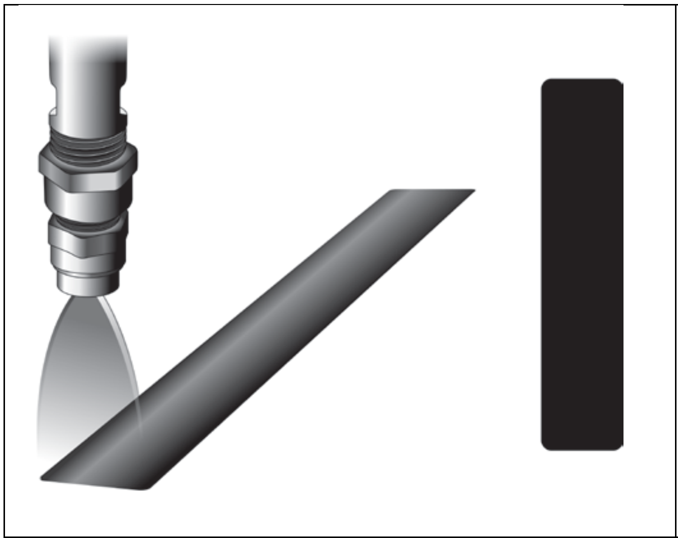


Figure 4. Film or Curtain Coater.
Applicator tip and spray pattern (left), top view of final pattern (right).

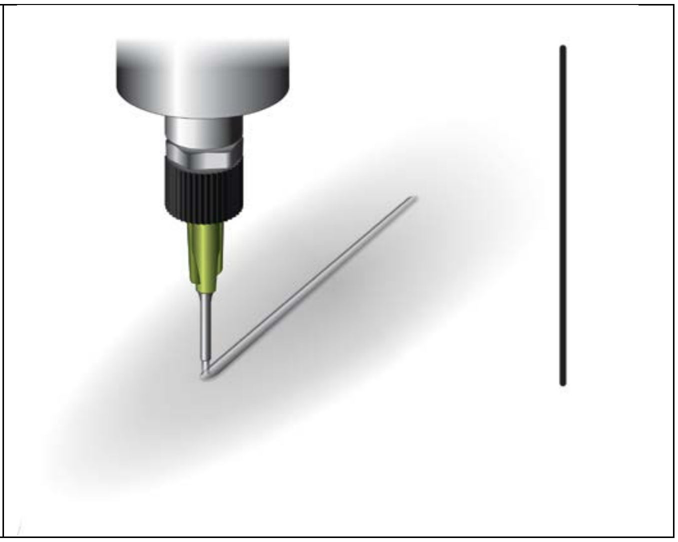


Figure 5. Needle applicator.
Tip and coating pattern (left), top view of final pattern (right).

In some cases, the needle applicators may dispense a dam or gel material to restrict material flow. Staking material, RTVs, and gels are commonly used to hold components or protect connector components from contamination by the regular coating material. While the time-pressure needle applicator is practical with a broad range on materials, it lacks precise volume control.

The jet applicator brings precise volume control and positional accuracy where the film coater or spray dispenses cause material to flood or contaminate Keep Out Zones (KOZs). The jet can dispense discrete dots spaced apart to reduce the material volume applied, yet close enough to flow and provide conformal coating coverage. The jet dispense pattern is depicted in Figure 6.

With the jet applicator, dots can be dispensed consecutively to form lines. Parallel lines can create area coats. Dispense volume can also be controlled through software. Pulse-width modulation is controlled through software and allows the operator to determine how long the applicator is opened and closed. Dot spacing can be controlled by timing or spacing distance. Appropriate spacing reduces splashing by not placing wet dots on top of each other.

The timing controls adjust the amount of material passing through the valve and the jetting actuation accelerates the fluid to break off. The capability of dispensing discrete dots distinguishes the jet from a needle dispense, which opens and uses fluid reservoir pressure to push the material through the needle.

Dispense needles are available in different gages, lengths, and shapes to best aid the application. The jet uses the same needle tips as the needle applicator. The variety of tip options allows both jet and needle applicators accessibility around tall components and can provide narrower dispense widths. The flexibility of the applicator allows for finely tuned conformal coating dispenses.

Benefits and Limitations of Pairing Different Applicators

A film coater and jetting applicator combination can enable high-volume manufacturers to create conformal coating programs to maximize control and selectivity, increase throughput, and reduce waste and rework. When working as a team, the film coater and the jet applicator balance speed and control.

By pairing the film coater with a jet or needle-type applicator, conformal coating programs can take advantage of the film coater's speed and broad passes while the paired applicator provides finesse and accessibility with the jet or needle. A dual applicator set-up allows the operator to dispense the border around key Keep Out Zones and proceed to the larger volume dispense applicator within the same program.

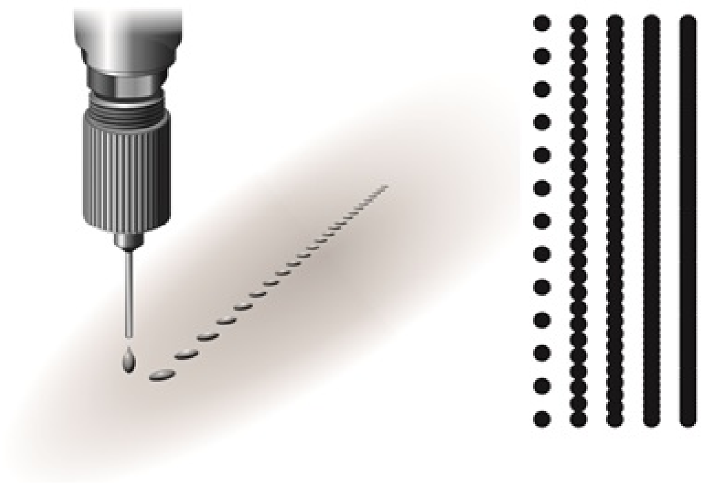


Figure 6. Jet applicator with needle extension. Tip and coating pattern (left), top view of possible patterns (right).

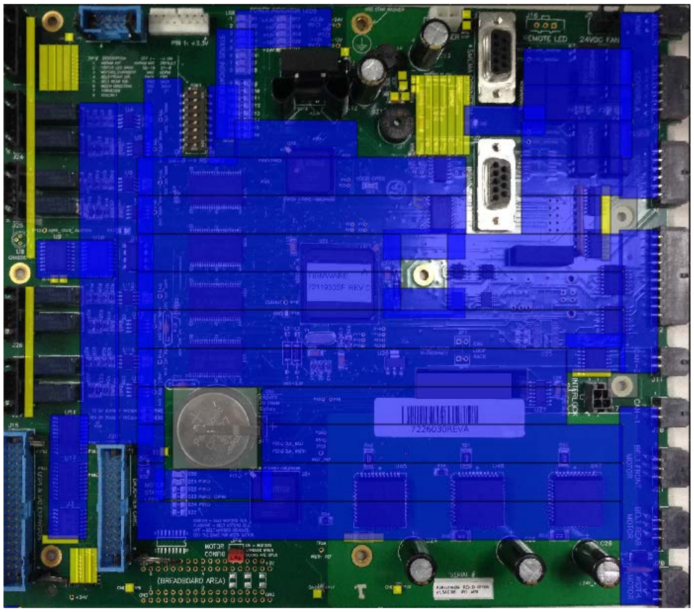


Figure 7. An image of a conformal coating program showing the dual applicator dispense. The blue pattern is the film coater area and the yellow is the detail work of the jet applicator.

The second applicator may have a needle extension for better access around vertical components. The jet applicator also has the most control of volume dispense of the listed technologies. When the process is run using the film coater primarily and paired with the jet's detail work, cycle time may be improved over a spray applicator moving at ~200mm/sec. The finesse of the jet reduces masking and rework. Figure 7 above illustrates a coating program utilizing a dual applicator set up to coat a board requiring large area coverage and fine detail work. Taking advantage of both applicators' strengths increases efficiency.

On an automated system, applicators are situated on the machine and the system can toggle the appropriate applicator as the program calls for it. Additionally, the applicators have various tilt and rotate options to further flexibility. Ultimately, a well-rounded automated coating system requires process controls to provide parameter maintenance.

Closed-Loop Process Controls for Conformal Coating Applicators

Automatic maintenance routines allow for closed-loop process controls for single and dual applicator set ups, which further improves performance during high-volume production.

A viscosity control system has utility in maintaining consistent coating despite temperature fluctuations in the production facility for a dual applicator set-up. By heating the material, fluid temperature remains consistent throughout the day and may reduce bubbles in the substrate coating. The theory is that by heating the material and thinning the viscosity, resulting bubbles are better able to escape from the coating. The viscosity control system works best with low-viscosity fluids dispensed with a film coater.

When dispensing with the film coater, maintaining the material shape and width is critical to a uniform dispense. Multiple factors can alter the dispense pattern, whether there is an environmental temperature change altering material viscosity, or an obstruction at the nozzle. A laser fan width control system can help maintain a consistent fan width throughout production. The laser fan width control uses a laser to measure the width of the fan pattern at the dispense gap distance from the nozzle bottom. If the fan measures outside specified tolerance, the system will adjust fluid pressure to best meet the required dimensions. Using an on-board laser fan width control system can measure the fan width at programmed intervals during a production run.

When using the needle and jet applicators, a needle-finder sensor can quickly determine the needle position. When changing needles or after an impact, the needle finder compensates for offset adjustments or recognizes the needle is bent out of alignment. It is important to verify the needle is not bent so that material dispenses in a clean stream straight down from the needle in order to maintain dispense quality. The needle finder can be used with both the needle dispense applicators as well as the jet applicator with needle extension.

Summary

Today, the majority of conformally coated, high-volume electronics are in the automotive, computer, communications, and consumer manufacturing segments. A large portion of those markets demand the use of solvent based coatings. Fortunately, this allows process engineers to benefit from a non-atomized conformal coating approach providing increased control, precision, and throughput over traditional atomized spray.

The non-atomized approach provides superior edge definition, higher coating speeds, and single-pass coverage over atomized spray techniques. The finer edge definition accommodates tighter Keep Out Zones while reducing or eliminating the need for masking. The film coater's faster line speeds and single-pass coverage translate to higher UPH. With the addition of a dual non-atomized applicator, jet or needle, the system can also accommodate smaller coating areas that may otherwise be impossible without using a mask. For high-volume manufacturers, automated selective coating systems provide an in-line, fully hands-off process that reduces or eliminates product handling by the operators, protects the coated products, and optimizes UPH and repeatability.

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