NEW COATING TECHNOLOGIES AND ADVANCED TECHNIQUES IN CONFORMAL COATING

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ABSTRACT
Conformal coatings have long been used to protect printed circuit boards in harsh environments in the automotive and military industries. Conformal coating has been traditionally applied with a number of techniques, including non-atomized film coating, non-atomized swirl patterns, atomized spray, and needle dispensing. Each of these techniques has their own strengths and weaknesses associated with edge definition, film thickness, and material compatibility.

As board density increases and new surface mount components are finding their way into harsh environments, traditional technologies limit the speed and/or precision required to apply materials. There are even new requirements for precision application of conformal coating materials to electronics packaging that are beyond the capabilities of traditional technologies and techniques.

The application of jetting technology expands the capability of conformal coating equipment with standard materials. Used alone or in conjunction with conventional technology, jetting can provide higher levels of precision, repeatability and than current methods. This paper explains jet coating technology and gives case studies where jetting can improve quality and productivity.

Key Words: Conformal coating, jet coating, film coat, tri-mode, flow coating, bead, swirl, monofilament.

INTRODUCTION
Conformal coatings are used to protect all kinds of electronic circuitry from moisture, dust, chemicals, solvents or other types of harsh environments. Although only a few hundredths of a millimeter thick, they are relied upon to dampen the effects of mechanical and thermal stresses, vibrations and electrical noise. Conformal coatings have also been utilized to control dendrite growth, a potential cause of short circuits. Initially, conformal coatings were reserved primarily for expensive aerospace or military applications. Today however, they are used almost everywhere. With the growth of portable electronics, increased demand for “smart” consumer appliance controls and continued growth in automotive electronics, conformal coatings are in more demand today then ever before. And while the demand for protected circuitry grows, the sizes of PCBs overall continues to shrink

There are many types of conformal coatings, each with its own specific performance characteristics. It is important to become familiar with these characteristics so that the proper material can be selected. The correct material for the application depends upon what the product needs to be protected from. Is it moisture? Dust? Vibration? High temperatures? Is it going under the hood of a car, into a washing machine or onboard a nuclear submarine?

TYPES OF CONFORMAL COATINGS
Conformal coatings are primarily classified by basic resin chemistry type. The five most common types are: acrylic (AR), urethane (UR), epoxy (ER), silicone (SR) and poly-par-xylylene (XY). A few hybrids consisting of blends of more than one type are also available. See Table 1 for short descriptions of these materials. Contact fluid formulators for details.

COATING METHODS
Manual Coating
The most common methods of manual coating are brushing, dipping and air spraying. Brushing requires the least amount of investment but is generally the least repeatable since it is entirely operator dependant. Care must be taken not to apply too much or too little. Too many brush strokes can result in bubbles, inconsistent coverage or brush fibers contaminating the coating.

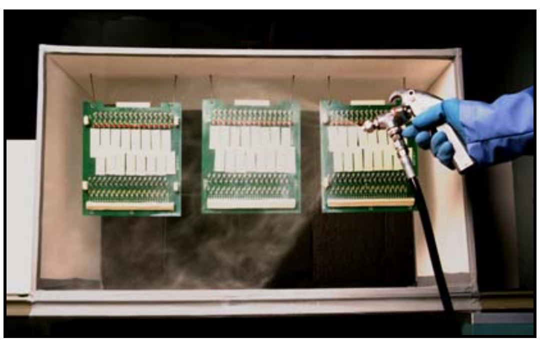
Dipping is a process that uses a tank of material into which the assembly is immersed and then retracted, usually at a specified rate. Obviously all areas not to be coated must be completely masked off prior to dipping. Even when automated, the masking and de-masking portions of a

Table 1. Types of Conformal Coatings

Material	Positives	Negatives
Acrylic (AR)	Inexpensive, easy to apply, dries quickly, good moisture and abrasion resistance, easy rework	Poor solvent and temperature resistance, only medium mechanical strength
Polyurethane (UR)	Excellent humidity resistance, higher mechanical strength, better solvent resistivity than acrylics	Difficult to remove, many are moisture sensitive, can be rigid
Epoxy (ER)	Excellent mechanical strength, humidity and abrasion resistance	Precise mixing requirements, short pot life, rework difficult or impossible
Silicone (SR)	Excellent temperature and humidity resistance, flexible	Poor abrasion resistance and mechanical strength, residue difficult to remove, potential contamination of other organic materials/products
Poly-par-xylylene (XY)	Very thin, strong, durable, complete coverage	Requires vacuum chamber, very expensive, removal difficult, batch type only

dipping process can be labor intensive and time consuming. Additionally, having an open vat of coating material on a production floor can pose a safety concern.

Manual air spraying is probably the most widely known method of coating PCBs. This method uses a spray gun that mixes a high flow of air with the material, creating a wide spray or mist. This process is wasteful since it generates over-spray. Masking and de-masking are usually required. Sometimes a spray booth may be used to contain excess over-spray or any harmful vapors.



Atomizing Spray Booth

Automated (Selective) Coating

Automated or selective coating is well suited for high volume applications where repeatability, speed and efficiency are essential for success. Selective coating uses a programmable robotic X-Y-Z positioning system to accurately manipulate the applicator in and around the product being coated. By using an automated system, repeatability, accuracy, operator safety and of course, product throughput are all greatly improved while at the same time material waste and VOC emissions are reduced. In most cases, the masking and de-masking processes can be completely eliminated.

Additionally, a well-designed software package will also provide enhanced process feature options such as flow monitoring of material, closed-loop viscosity control, optical recognition of matching a specific program to a specific product, closed-loop fan width control and graphics import for board identification and statistical process control features for traceability. The software and platform must also be able to readily accommodate a wide range of applicators.

AUTOMATED COATING TECHNOLOGIES

Selective Needle Dispensing

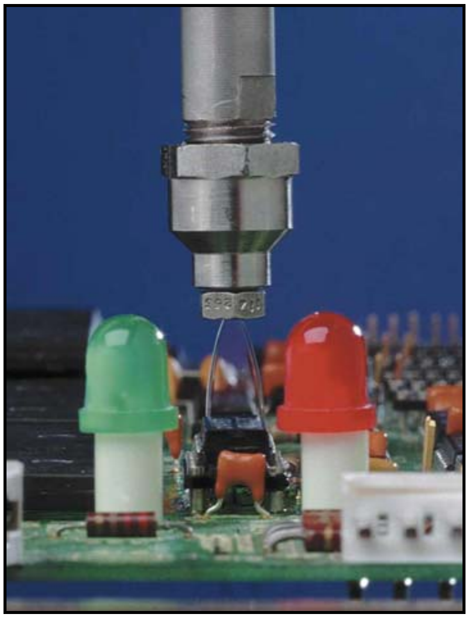
Needle dispensing, sometimes referred to as “flow-coating,” can be automated to make it more repeatable. However, even with automation it still has some drawbacks. Since the material shutoff point is typically some distance from the actual needle tip, drips are common. Additionally, material can cling to and climb up the side of the needle, resulting in blobs or uneven lines. Small gage needles are delicate and can be easily bent out of position. Also, the bead produced may result in a film build that is too high or the bead may be too small to cover large areas practically. Nonetheless, with proper programming and procedures, selective needle dispensing can be an effective means of applying conformal coating, particularly in areas that are difficult to reach.

Ultrasonic Coating

Ultrasonic coating technology uses a piezo-electric transducer to transform an electrical signal into mechanical vibrations. The transducer, vibrating at an ultra-sonic frequency agitates the coating material until it becomes atomized. The atomized mist is then generally directed towards the substrate by a controlled air flow. Generally, ultrasonic coating technology is appropriate for very low viscosity materials. It has the ability to produce a very fine mist, which can result in some very thin film builds. However, ultrasonic coating platforms can be sensitive to ambient air currents and machine vibrations.

Selective Film Coating

Film coating solves many of the problems associated with needle dispensing. A film coating applicator uses a special crosscut nozzle, which is much more robust than a needle. The geometry of a crosscut nozzle produces a fan-shaped, non-atomized curtain of coating. This applicator is a time/pressure type, incorporating needle and seat valve technology. A spring forces a needle into a seat, shutting off fluid flow. When a trigger signal is received, air pressure through a solenoid overcomes the spring force, lifting the needle and opening the seat. Fluid pressure forces the material out through the nozzle. Unlike needle dispensing however, the crosscut nozzle can withstand the rigors of brushing or wiping during maintenance routines.



Non-Atomized Film Coat Fan Pattern

Fan widths typically range from 6-19mm. By orienting the fan perpendicular to the length of the programmed line, a wide coating stripe is achieved. Running the fan parallel to the line results in a "knife-edge" pattern for narrow areas or spots. For maximum flexibility, a rotate mechanism on the applicator allows automatic switching to either orientation for any given programmed line. This allows full coverage in both the X and Y axes. Each stripe can be programmed at a specific orientation, direction, speed and dispense height in order to achieve the desired results.

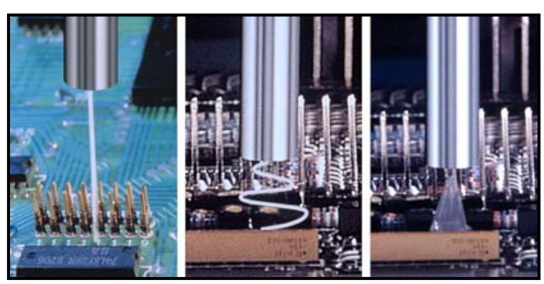
Film coating is usually the dispensing method of choice when the material viscosity is less than 100 centipoise. Since film coating is entirely non-atomized, the resulting pattern has a very distinct edge. This can be crucial to many applications where overspray from an atomizing spray valve may not be tolerated. Typical film builds with a film coater are usually between 0.02-0.20mm with line speeds of up to 510mm/sec and edge tolerances as good as +/-0.762mm. Film builds can be easily controlled by adjusting the percentage of solvents and/or the robot's speed.

Selective Tri-mode Coating

For many applications, more than one dispensing method may be needed for effective coverage. Tri-mode dispensing technology combines the wide area benefits of an atomized spray with the selective benefits of a non-atomized bead, all within a single applicator. This single applicator can produce three distinctly different patterns: non-atomized bead, non-atomized monofilament and atomized swirl, or spray. By combining three patterns into one cost-effective applicator, flexibility of the dispensing system is maximized, allowing for accommodation of a much broader range of applications. Additionally, the three modes are accomplished without sacrificing dispense area. Typically, tacking on two or three separate applicators to a robot's head can drastically reduce the system's overall effective dispense area.

Tri-mode Applicator

The tri-mode applicator has a unique co-axial air assist feature. It is the precise control of this coaxial air assist along with control of fluid that allows three patterns to be produced from one applicator. By adjusting the direction, angle and flow of the coaxial air assist, a wide range of swirl and monofilament patterns is possible. A relatively low fluid flow rate with a relatively high air-assist flow rate produces a finely atomized conical spray pattern. A relatively high fluid flow rate with a relatively low air-assist flow rate produces a non-atomized monofilament pattern. By turning on the fluid without any air-assist, a solid stream of material is dispensed to create non-atomized lines or small spots.



Bead, Monofilament, and Swirl Spray Patterns

The width of the swirl and monofilament patterns is controlled by adjustment of the angle and the flow of the air assist air. By combining adjustments of both the angle and the flow, a broad range pattern widths is possible from very narrow for tight access areas to very wide for large area coverage. Pattern widths with a tri-mode applicator can range from 2.5mm in bead mode up to 19mm in monofilament mode with line speeds of up to 510mm/sec. Typical edge tolerances can be +-0.635mm in bead and monofilament modes and +-1.5mm in swirl mode.

Overall fluid flow rate on the tri-mode applicator is controlled by a combination of nozzle size, a valve opening control and fluid pressure. Balancing the valve opening control with fluid pressure allows equivalent fluid flow rates to be achieved for various selections of nozzle sizes.

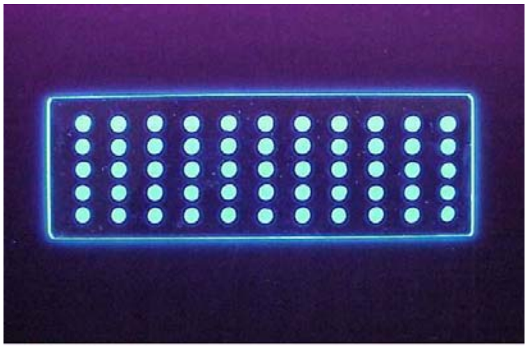
Table 2. Effects of Fluid Flow Rate vs. Air Flow Rate Using Tri-Mode Applicator

Fluid flow rate	Air flow rate	Resulting pattern
Low	High	Atomized spray
High	Low	Monofilament
High	Off	Bead

Precision Jet Coating

As with many manufacturing processes, the continued drive to shrink board size and increase component density poses new challenges for coating as well. A growing number of tiny circuit boards, flex circuits and high-density packages have requirements that exceed the placement and volumetric accuracy limitations of existing coating technologies. As a result, many of these smaller applications such as hearing aids, multi-chip modules, pagers, numerous medical devices and a myriad of automotive sensors are being coated very tediously by hand, sometimes under a microscope. Fortunately a new coating technology exists today that offers the potential for increased selectivity, repeatability and throughput – jetting.

Having already proven itself in surface mount adhesive, no-flow underfill and flux applications, jetting technology is becoming more and more useful in many coating applications that require highly accurate and repeatable placement of very small amounts of material.



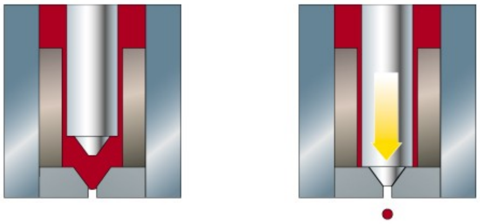
2.5mm Acrylic Dots Jetted onto Glass Slide

Jetting Demystified

So just what is jetting and how can it be applied in a conformal coating process? A jet applicator is essentially a needle and seat valve. One major difference however, is how the material comes about leaving the nozzle. With traditional needle and seat technology, a fluid is fed into a chamber under constant pressure. At the bottom of the chamber is a seat, or outlet port of the chamber. Inside the chamber is a needle. The bottom of the needle is positioned such that it protrudes into the seat and is held there via a compressed spring, sealing off the fluid chamber. The top of the needle is sealed off from the fluid by seals and is inside an air chamber. When this air chamber is pressurized with enough pressure to overcome the compressed spring pressure, the needle’s piston lifts the needle tip off the seat, allowing fluid to flow out of the chamber. When the air pressure is released, the spring returns the needle’s tip, sealing off the seat and shutting off fluid flow.

With a jet applicator, the geometric relationship of the size and shape of the needle to the size and shape of the seat is very specific. The two are designed such that when the needle returns to the seat, a short pressure spike is created in the chamber, accelerating the fluid rapidly and ejecting it out of the nozzle in the form of a droplet. It is this impact of energy that allows a clean snap-off material from the nozzle tip, an action simply not possible with a standard needle dispenser.

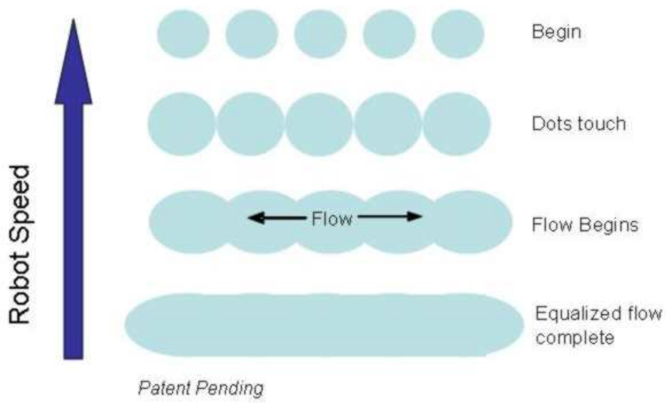
Conformal coatings are designed to stick to whatever surfaces they come in contact with, including the dispensing needle or nozzle itself. They can be difficult to separate from the tip, particularly when trying to dispense small dots. Frequently when dispensing conformal coatings through a standard needle valve, the material tends to drip and drool and eventually, a clog. With its pressure spike snap-off action, jetting technology alleviates that issue.



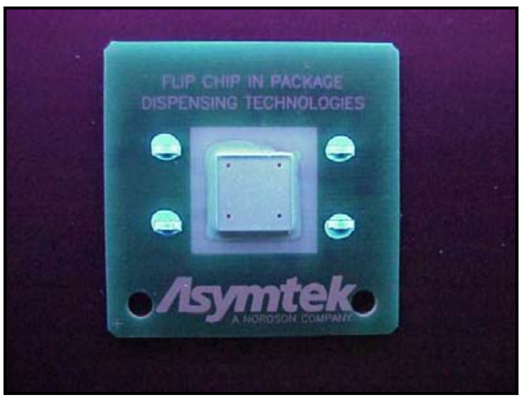
Needle Impacting Seat Ejects Droplet of Coating

Individual dot sizes through the jet applicator are controlled by variation of needle size, micro-adjust, pre-load spring pressure and valve on time. By spacing adjacent dots appropriately then stepping and repeating, larger areas are covered.

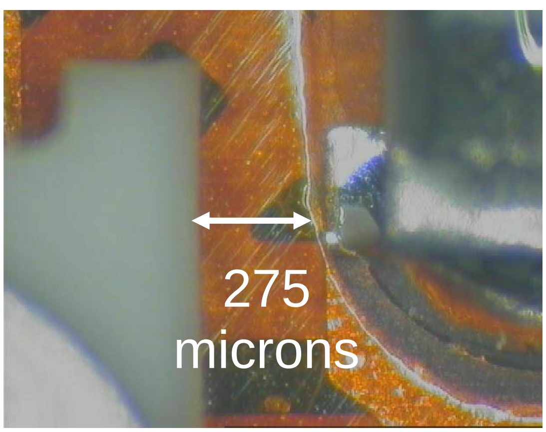
The jet applicator can produce individual dots in “spot” mode, or the dots can be stitched together in what is called “line” mode. For a given jet frequency (time between shots), as line speed is decreased, the density of the dots increases until eventually they are compressed enough that they flow together to form a line. First, a scalloped line is formed and then a straight line. Multiple lines can then be combined separately or as larger "area coats" to generate a very precise pattern.



Jetted Dots of Material Compress and Flow Together

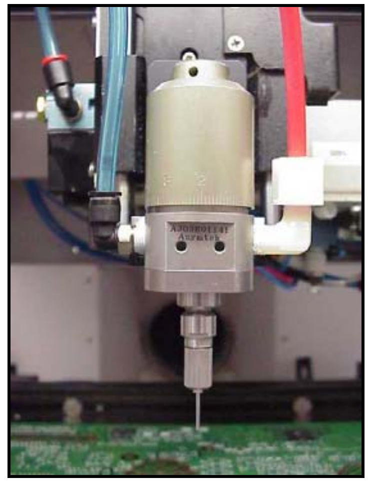


Jet-Coated 0805 Resistors Around Underfilled Chip



Jet Coating Inside Tight Keep-Out Areas on Flex Circuit

Another advantage of the jet coating applicator is that it uses a standard dispensing needle at its very tip, thus combining the benefit of the snap-off jetting action with the deep-accessibility of a needle. The needle, along with the jet body's overall slim design, provides better access to components otherwise not reachable by most standard spray coating valves, which tend to be relatively bulky. Consequently, the needle's tip can be brought down to just above the components and/or substrate (typically <5mm), enhancing placement accuracy while also reducing splash. The jet's nozzle is designed to accept a variety of gages (typical 18-22 gage) and lengths (typical 13mm) of low-cost standard dispensing needles, providing flexibility as well as low cost of ownership



Jet Coater with Typical 13mm Needle

Finally a third major advantage of jetting technology is more precise flow control – a crucial feature for maintaining a consistent pattern and avoiding encroachment into close keep out areas.

The dot on and off times are primarily what controls how long the jet seat is open and closed, and therefore how much material passes through for each dot. By adjusting these on and off times and coordinating them with the robot's line speed, the flow rate of material can be electronically controlled and varied. This method of modulating on and off times in order to vary material flow provides a level of control unparalleled by conventional mechanical regulators – a huge benefit for coating in many of today's challenging applications.

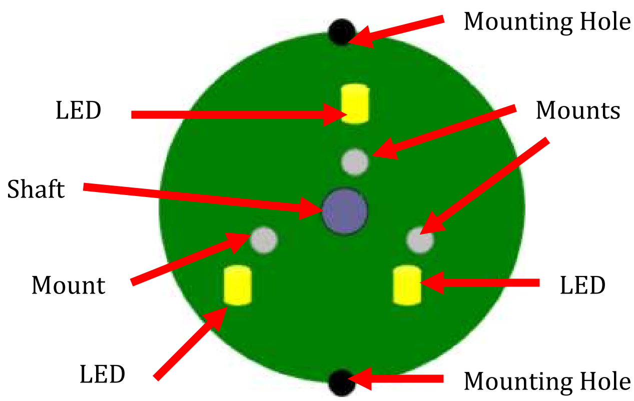
COATING CASE STUDIES

Following are examples where standard conformal coating applicators could not provide the precision necessary to accomplish the task. In all cases, the only existing alternative was to resort to time-consuming manual processes. In most cases, masking and de-masking were also required.

Case #1

Coating of 50-mm (2-inch) diameter round circuit board with nine keep out areas. Volume: High. Current Process: Masking and hand-coating with brush, resulting in highly variable quality depending on operator skill, low productivity.

Solution: By using automated jet coating, repeatability and throughput were greatly improved. Masking was eliminated.



Round PCB (50mm /2-Inch Diameter)
With 9 Keep-Out Areas

Case #2
Coating all 120 leads of a 25mm square gull-winged QFP, some leads immediately adjacent to keep-out test points. Volume: High. Current Process: Automated spray and hand coating with brush, resulting in highly variable quality depending on operator skill. Low productivity, flow out into keep-out areas.

Solution: By using the automated jet coater, the precise amount of material was repeatably placed directly on the leads, providing consistent and full coverage, with no flow out into keep out areas.

Case #3
Coating of 04/02 SMT devices placed <1mm away from a keep out ground plane. The components ran for approximately 100mm along the ground plane. Volume: High. Current Process: After attempting to use automated coating; ultimately had to hand-coat with brush, resulting in low to medium quality depending on operator skill, with low productivity.

Solution: By using automated jet coating, repeatability and throughput were greatly improved.

CONCLUSION
The demand for conformal coating continues to grow and become more diverse every day. Coated products come in an endless array of shapes and sizes ranging from large motherboards and complex panels to small modules, tiny PCBs, flex circuits and individual substrates. Markets served include automotive, commercial, avionics, military, consumer and medical. Add to this a multitude of coating materials to choose from, each with its own specific properties. Soon it becomes obvious that no one system or process can accommodate everything. A particularly growing trend recently has been the need to address smaller and smaller packages, which requires even more creative dispensing methods with increased accuracy, selectivity and repeatability. With the right expertise, jetting technology can provide these capabilities and extend the range of conformal applications to include those that are just too small for traditional coating valves. Leading edge global dispensing companies will continue to develop and enhance new technologies in order to address new challenges as they arise.

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