

## Process control and traceability in automated conformal coating

# Stringent quality standards

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*Conformal coating continues to evolve in materials and production equipment. This evolution is being driven by market forces that include environmental concerns, higher density electronics, and higher levels of automation. Drivers from traditional markets such as automotive, military, industrial, and white goods, also benefit new markets such as medical and handheld devices. This article focuses on the important factors and their effects on successful coating using the traditional Ishikawa diagram (cause and effect diagram).*

The result of the mentioned evolution includes low volatile organic compound (VOC) materials, equipment that provides better selectivity of material, better process control, and traceability. In particular, the growth of the use of conformal coating in automotive safety devices, such as airbag sensors, high-volume handheld electronics, and medical electronics that have stringent quality standards, puts higher demands on quality control.

Cause and effect analysis using a fishbone diagram was formalized by Dr. Kaoru Ishikawa in the 1971 publication, "Guide to Quality Control". In this analysis, the process engineer is called to identify all the factors that affect the desired outcome of a production process. This diagram is then used as a basis for developing the Statistical Process Control strategy for ensuring quality in the process, including setting the specification limits,

monitoring the control limits, and providing traceability of other factors. While it is beyond the scope of this article to carry this analysis to conclusion, the important first steps can be given as a guideline.

### Specifications and requirements

Most conformal coating applications have specifications that describe the desired out-comes centered around the following requirements:

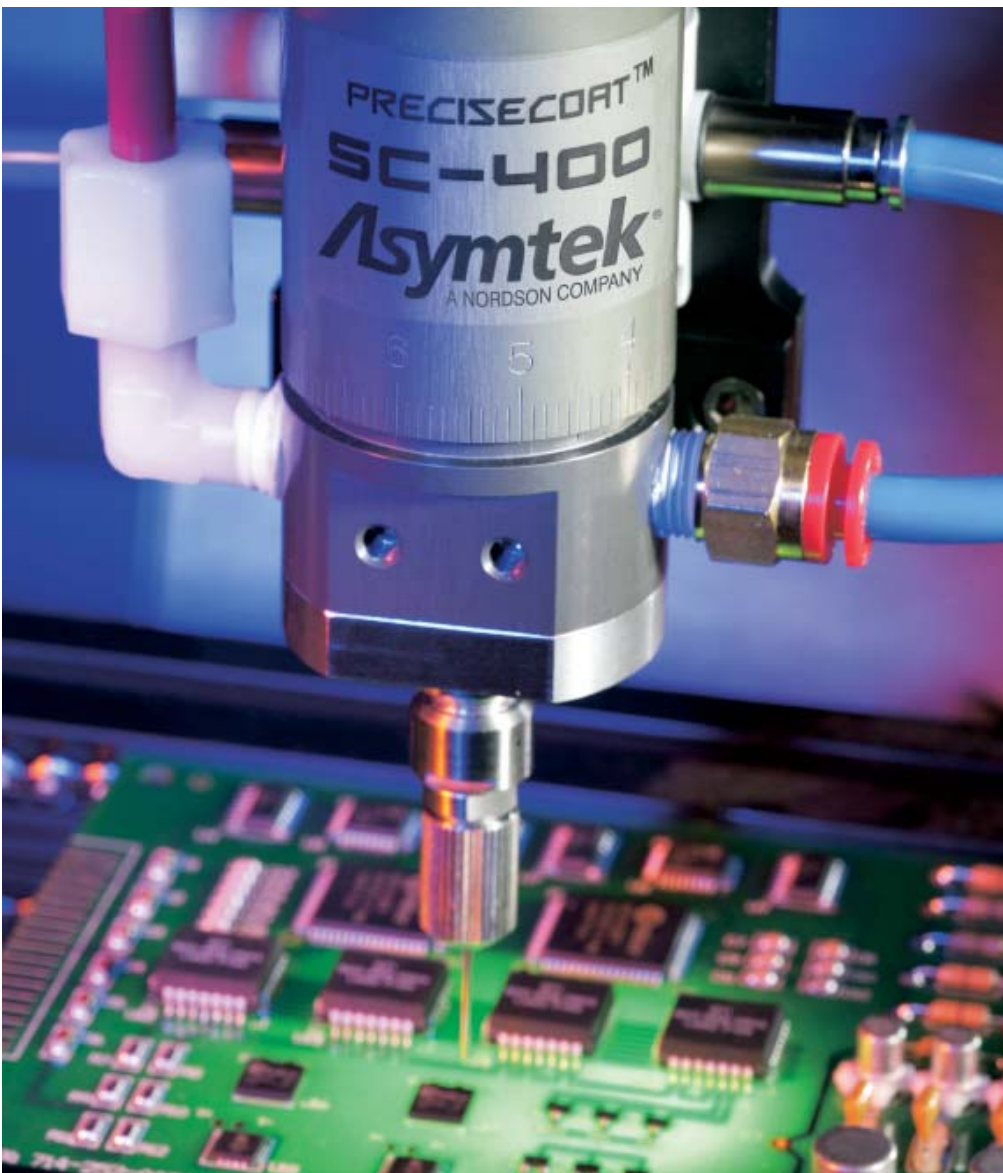
1. Required coating areas – These are the areas that must be coated to provide the desired protection.
2. Moisture, chemical, and/or mechanical resistance to the environment in which the product will be used.
3. Keep-out zones – These are areas that coating must not cover for purposes of electrical connection or other functions.
4. Chemical compatibility of the coating material with the device or the environment in which it is used (such as medical applications).
5. Maximum tact time, which is the time to manufacture one unit.
6. Maximum allowable volatile organic compound emissions
7. Operator safety
8. Maximum allowable cost of ownership or desire to minimize the cost of ownership.

All other requirements, such as coating thickness and edge definition, flow from these desired out-comes. Typical derived production requirements include:

1. Coating material
2. Minimum and maximum coating thickness (often simplified by military or industrial standards)
3. Edge definition (the distance between where the coating meets the minimum thickness requirements and where there is no coating material, that is, the distance between required coating areas and the "keep-out" zones).

For the purposes of this article, it is assumed that a coating material has been selected and a process has been developed for a specific part. This is not a trivial process and is best done in partnership with the material supplier and equipment supplier. Once the process has been developed to meet the requirements, the quality of product is primarily in-

Figure 1: System shown with viscosity control plumbing



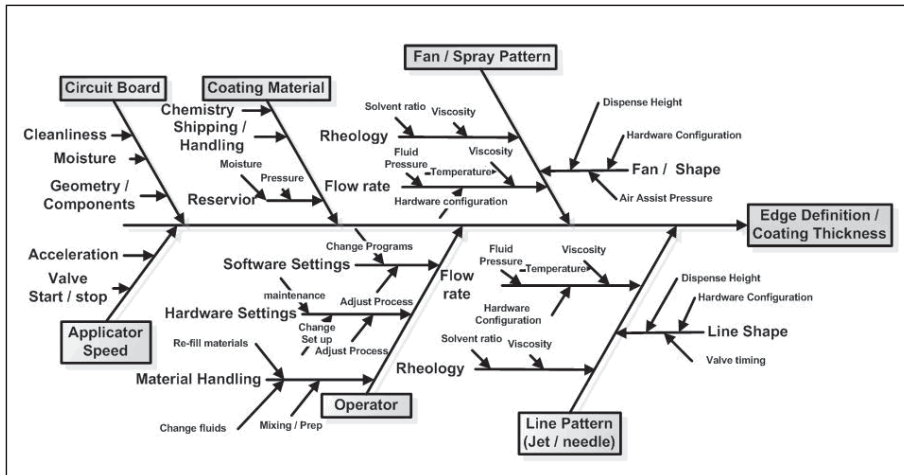


Figure 2: Generalized cause and effect diagram for conformal coating

fluenced by the edge definition, coating thickness, and adhesion of material to the substrate. Material adhesion is largely dependant on surface preparation and material choice and not addressed here. Figure 2 shows a generalized cause-and-effect diagram for edge definition and coating thickness. For a specific process, some of the "causes" may not apply, depending on the applicator and material used.

### Process control

Controlling the quality means controlling the variables that "cause" process variation. It is apparent in figure 2 that there are several common "causes" of variability in both edge definition and coating thickness. Here, we discuss strategies for controlling some of these variations with automated equipment. These strategies generally include:

1. Have standardized hardware with specific settings documented to reduce operator error. In the parlance of lean manufacturing, this is "standard work". Moving as many of these settings into the software where they can be computer controlled and locked out from operator interaction is a good strategy to reduce operator variability.
2. Monitor key process variables (automatically or manually). Automating this through electronic logging can help in troubleshooting.
3. Set control limits for key process variables.
4. Automate warnings when key process variables exceed control limits to prevent making bad parts.
5. Use closed-loop control to compensate for uncontrolled variables.

Specific strategies for temperature control, flow rate monitoring, fluid pressure control, preventing material contamination, and operator variation are discussed.

### Temperature control

Temperature of the coating material shows up in the fishbone diagram in several places. Changes in temperature can change viscosity, material flow rate, fan patterns, spray patterns, pot life, and wetting. Any of these can change coating thickness or edge definition. Closed-loop temperature control of the fluid, process alarms, and data logging are all good strategies.

Dip cups used to measure viscosity of materials are frequently employed to verify the viscosity and calculated solids content of a batch of material. There are many standards for dip cups, including DIN, ISO, Zahn, Ford, and Shell. While this verifies the viscosity at a given ambient temperature, changes in the ambient environment can negatively impact process stability. A closed-loop temperature control system for the fluid can ensure a consistent process that isn't changed by ambient temperature variation. Figure 1 shows a dispensing system with viscosity control plumbing.

### Flow monitoring

Since the robot of an automated coating unit moves at a substantially repeatable speed, the volume of material that is applied to the product is directly dependant on the flow rate. This directly affects coating thickness and edge definition. Monitoring, logging, and setting limit alarms can be very effective in detecting a large number of problems that can cause poor quality.

### Fluid pressure control

Fluid pressure also shows up in figure 2 in multiple places in the cause and effect diagram and interacts in several ways with coating thickness and edge definition. Most systems use mechanical closed-loop pressure regulators as a



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minimum. System monitors, limit alarms, and automated logging go further to control quality. Putting fluid pressure under electronic control also creates an opportunity to move the control into software, using pressure in other closed-loop systems, and preventing variations from user interactions.

## Pattern width control

Pattern width, both atomized and non-atomized, is affected by many variables shown in figure 2, variations in the fluid being the largest uncontrolled variable. Pattern width has a direct effect on both coating thickness and edge definition. Using the relationship between the fluid pressure and the pattern width allows for the design of a closed-loop control system that keeps pattern width substantially constant. For this to be successful, an effective way of measuring pattern width must be used.

## Material contamination

Material contamination can have a dramatic effect on coating quality in ways other than what are addressed here. In this case, prevention is the best cure. Many fluids are sensitive to pressurized gas or moisture. Pressurizing fluid with dry nitrogen prevents contact with moisture. Bagging systems prevents direct contact of fluid with pressurized gas and moisture. Since mishandling of material prior to use in automated systems can also create quality problems, the combination of logging material batches and logging production parts with RFID or barcode readers can assist in troubleshooting or containing quality problems.

## Operator variation

The use of automated equipment is often driven by improving both speed and quality; however, mistakes by operators of automated equipment can result in the production of poor quality parts at high speed. Many of the strategies described in this article such as flow rate monitoring, can have the benefit of detecting operator variations. Moving mechanical settings to software settings can take the operator out of the process to prevent variations. Typical software has security levels that prevent the operator from changing critical variables. Again, production logging and part tracking through RFID or barcode readers can help troubleshoot or contain quality problems. Lastly, Poka Yoke (error proofing) techniques for equipment design can reduce variations where operator interaction is required for maintenance.

Beyond quality control: speed, cost, and environmental concerns.

## Speed and Cost

While the need and benefits of automation are often driven by quality, cost is an important driver for automation. Virtually any cost of ownership model will show that increasing the speed of production is one of the most important factors in reducing cost of ownership. One industry standard model, SEMI E35, shows this relationship and other factors that influence the total cost of ownership by dividing the production cost for a

piece of capital equipment over its lifetime to the total number of units produced. Often, the initial price of the equipment is a fraction of the overall production cost. Well-designed equipment that costs a little more can dramatically reduce the overall cost of production. When products are produced faster with a given set of resources, the "per unit" cost is lowered. Other factors are not so obvious, but fortunately line up well with good quality control practices. They include:

- Increasing yield, which can have a bigger influence on speed depending on the value of the parts produced.
- Reducing material waste, which depends upon good control of coating thickness and edge definition.
- Reducing setup and equipment assist time.
- Reducing equipment maintenance and repair time.

## Environmental concerns

The conformal coating industry has been driven to materials changes due to environmental regulations to reduce VOC emissions from production facilities. Strategies for reducing VOCs include: first, materials with solvents that do not include VOCs, second, materials that have reduced amounts of VOC solvents, and third, materials that use alternatives to solvent drying. In the first case, materials with VOC free solvents require significant formulation and process changes. These include the "water-based" materials. While this is a direct approach to eliminating VOCs, the materials available do not cover the broad spectrum of requirements of most coating processes and have not been widely adopted.

The second approach, reducing the amount of VOC solvents in a material, is an alternate, lower risk, short term solution because it does not require re-qualification of the existing materials. In this case, it places a heavier burden on the coating equipment to apply the material in the desired way. The use of automated viscosity control systems can help. Environmental regulations put an upper limit on the total VOC emissions. The advantage to this approach is that a reduction in VOC solvents can enable a proportional increase in production capacity without changing the basic material chemistry.

The third approach mentioned, materials that use alternatives to solvent drying, is gaining larger acceptance. This broad class of materials is referred to as "100% solids", meaning they contain no solvent to evaporate. Materials formulated with UV, moisture, or thermal cure fall into this category. While they are being developed to reduce VOC emissions, there are other benefits. The use of UV cure materials is more attractive to the medical device market for stringent bio-absorption issues. They can also reduce production line length due to shortened cure times compared to traditional solvent based drying times.

## Conclusion

The conformal coating process can be improved by applying quality control strategies. When implementing these strategies, the best results will come from close partnership with the material supplier and equipment supplier. The techniques for tracking, controlling, or eliminating the

sources of process variations will result in better coating. The benefit of good process control is reduced cost of ownership. Equipment that costs more initially, but supports process control, may have the lowest cost over time.

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## ZUSAMMENFASSUNG

*The growth of the use of conformal coating in automotive safety devices, such as airbag sensors, high-volume handheld electronics, and medical electronics that have stringent quality standards, puts higher demands on quality control. The conformal coating process can be improved by applying quality control strategies. When implementing these strategies, the best results will come from close partnership with the material supplier and equipment supplier. The techniques for tracking, controlling, or eliminating the sources of process variations will result in better coating. The benefit of good process control is reduced cost of ownership. Equipment that costs more initially, but supports process control, may have the lowest cost over time.*

## RÉSUMÉ

*L'utilisation croissante de revêtements enrobants aux normes de qualité très strictes dans les dispositifs de sécurité automobiles comme les capteurs des airbags, l'électronique portative grand volume et l'électronique médicale accroît la demande en contrôles qualité. Le processus de revêtement enrobant peut être amélioré par certaines stratégies de contrôle de la qualité. Dans la pratique, ces stratégies donnent les meilleurs résultats lorsque les fournisseurs en matériaux et en équipement travaillent en très étroite collaboration. Les techniques de suivi, contrôle ou d'élimination des causes de variation des processus permettent alors une amélioration du revêtement. Un bon contrôle des processus permet ainsi de réduire le coût total de possession. Les équipements dont le coût d'investissement initial est élevé mais qui assurent un contrôle des processus sont susceptibles d'être les plus rentables à terme.*

## SOMMARIO

*L'aumento dell'utilizzo del conformal coating nei dispositivi di sicurezza per le automobili, quali i sensori airbag, l'alto volume di prodotti elettronici portatili e i prodotti elettronici a uso medico che richiede elevati standard qualitativi, richiedono un maggiore controllo della qualità. Il processo di conformal coating può essere migliorato impiegando strategie per il controllo della qualità. I migliori risultati si ottengono collaborando da vicino con il fornitore dei materiali e il fornitore delle attrezzature. Le tecniche di tracking, controllo o eliminazione delle cause di variazione dei processi produrranno un coating migliore. Il vantaggio di un controllo efficace dei processi è la riduzione del costo di possesso. Le attrezzature con un maggiore costo iniziale, che supportano il controllo di processo, possono avere il costo più basso nel tempo.*