ABSTRACT

Conformal coating is a thin, transparent coating that ‘conforms’ to the contours of the board covering the electronic circuit boards & protecting the electronics components from the corrosive effects of the environment, typically applied at 50-250 μm. The products that are normally subject to harsh environmental conditions can benefit by having conformal coatings and will improve their reliability and endurance, also increasing their operational longevity. In addition to shielding the components, conformal coatings also mechanically strengthens and protects them, making them more able to withstand mechanical stress which is common during the temperature cycle of a product’s operation.

In an electronic product’s built process, conformal coating is most typically applied after functional test is successfully performed on the circuits. At this stage of the process, all the connectors are installed and the circuits are cingulated (de-panelized). Due to this nature, the inline automated application and inspection of conformal coating is most likely done on a line that is separated from the automated assembly line that builds the circuit in the first place. This line will include an automated dispensing machine that dispense the conformal coating, a curing oven that cure the conformal coating; followed by an automated conformal coating inspection machine.

There are areas on the board where it is particularly important to have the protection of the conformal coating. Typically these are the metal leads of the electronics components. On the other hand, it is also important that certain area of the board be completely free of coating. This is called the “keep-out” area. Typical keep out areas are connectors that carry the electrical signals to other circuits. Lastly, there are areas of the board where have or not have the coating is simply optional; we call these areas the “Optional” areas.

Different masking techniques can be used to ensure the keep out area is free of coating; using masking tape is one of them which are labor intensive and very hard to automate. Since conformal coating is done after functional test, board fixture is commonly used to hold the boards. A specially designed fixture can be used to cover the all connectors on the edge to prevent the conformal coating from getting onto them. Such a fixture automatically masked out all edge connectors. Rather than masking, another completely different approach is to use the automated dispensing machine to selectively apply the coating only to the areas that needed the coating.

Similar to the previous production stages, quality of applied coating must be assured. After coating the assembly, proper wetting is mostly visibly checked by manual means in a special darkened area so that the fluorescence stimulated by UV light can be observed by the inspector using a magnifying glass (main method used by > 90% of the electronics manufacturing world), with the usual manual optical inspection disadvantages, among them are that the results are dependent by Inspector experience + Inspector to Inspector variability, it requires higher working space allocation, usually means increased work in progress (WIP), has inadequate product handling with non or reduced traceability and data storage, inspection, hazard & safety awareness training are required, since UV light required for inspection could potentially damage Inspector eyes.

Besides this, required magnification for inspection keeps increasing as electronics miniaturization continues moving forward. Per IPC & depending on minimum defect size detection, 5 - 10X magnification usually suffices for current conformal quality standards, however customer and new technology requirements keeps increasing the complexity of the inspection, fortunately magnification of automatic inspection systems typically comply and surpass these requirements.

AOI, Spectral Interference Laser Displacement.

AUTOMATED CONFORMAL COATING INSPECTION

INTRODUCTION

Automated Conformal Coating Inspection (ACI) is the application of the Automated Optical Inspection (AOI) techniques to inspect the quality of conformal coating on a circuit board, basically by converting images to BLOBs and analyzing pixel brightness and coverage of required areas.
Same as AOI, ACI are systems are an assembly of cameras, lighting and X-Y stage autonomously scans the PCB taking images that are analyzed by a processing software, basically by converting images to BLOBs and analyzing pixel brightness and coverage of required areas, providing a controllable and traceable process to verify the quality of the conformal coating. The only difference in ACI is that the lighting used is UV. Blob analysis allows to identify connected regions of pixels within an image, then calculate selected features of those regions (same logical pixel state based on a given determined criteria). Software uses a user-specified blob identifier to discriminate between blobs and the background, afterwards, can calculate a variety of different blob measurements or features, such as the area, dimensions (since each pixel in the image represents a real width and height for example, in microns), and based on camera magnification, software converts these results to actual physical units.

With minimal programming, the inspection setup is fast and intuitive typically requiring less than 10 minutes. A known good board is used to learn the coverage and non-coverage areas. Same as AOI, its main advantages includes much higher throughput with a cycle time normally around 20 seconds (with a smaller footprint), a higher and flexible magnification ranging from 1.5X – 30X and since inspection is computer/robot aided results are highly repeatable & non Operator dependent. In line set up is usually the chosen method and since can also read a barcode on PCB and store the inspection results on a database can easily be integrated with factory material traceability systems.

**UV Tracer Requirement**

UV tracer has to be added in the conformal coating material to facilitate the visual inspection of the conformal coating as per qualification requirements noted within the industry specifications IPC-CC-830. Since the tracer fluoresce, it converts the invisible UV light to visible blue light. And make the conformal coatings glow blue under UV illumination.

**UV (Ultra Violet) Light**

This UV-based AOI systems require a specific wavelength of light (typically ranging between 350 - 365 nm) to be shined over the coating material in order to activate the florescent tracer inside, which is the central scheme of the conformal coating inspection. Several measurements needed in the conformal coating inspection depend on the consistence of the UV lighting, therefore considerable efforts are taking into consideration to ensure the quality of the UV lighting. Through experimentations it is found that there are two main types of variations regarding the UV lighting.

The first is the non-uniformity across the field of view, that means that the brightness varies depending on the location within the field of view of the systems camera, this is usually also called “area variation”. The second type is a time dependent variation, meaning that the intensity of the UV light changes over time, mainly it will get brighter as it warms up.

To compensate for non-uniformity across the field of view of the UV lighting, specialized algorithms and a matrix of scaling factors can be used during calibration by measuring the bright nesses across scanning area. During inspection the system uses those scale factors to normalize the variation across the field of view. The absolute value of those scale factors will also ease troubleshooting in order to determine if there were any hardware problem with the lighting itself.

The Uniformity calibration and verification is part of the self-testing process of the software. To compensate for the time related variations, a UV florescent target can be installed on the rail of the conveyor in order to ensure the proper warm-up and stabilization of the UV light before the inspection begins.

**Conformal Coat Inspection Algorithms & Inspection Methodology**

Basically there are two approaches for doing conformal coating inspection by an AOI, the first approach and simplest one is the grid based where a complete grid of inspection boxes is placed over the board and the brightness value and coverage area of each ROI (region of interest) are evaluated using the inspection algorithm. The second approach is a component based approach where the focus is only on the actual parts of the circuit and basically smaller version and different algorithms are used to evaluate various region around the part for coating defects. Although the two approaches are markedly different that does not mean they cannot co-exist.

The grid based approach is quick and easy to setup but have limited inspection depth. The component based approach is more complex to setup but can check for multiple types of conformal coating defects, and also provides increased reporting and traceability functions. When using a part based
approach a package library can be generated and will greatly speed up the process of recipe creation and debugging.

Figure 3. Component based approach (left) & Grid based approach (right).

### Single Sided or Dual Sided Inspections

Different manufacturing processes may require different test methods, cycle times and different inspection stages, however conformal coating is likely need to be applied to both sides of the circuit board, so board flippers are common on a conformal coating line. In the line setup below, both the Dispenser and the ACI Machine is capable of double-sided operation, in which after the first side is done the board is fed left into the flipper to flip to the second side then re-enter the machine for operation on the second side.

In order to accomplish more complex inspections, a downward viewing camera is used for top-side inspection along with four side angled viewing cameras, and same concept can also be used for bottom side, by a secondary camera gantry with upward viewing cameras for bottom-side inspection, generating a complete view of PCB under inspection area, emulating an all side human inspection. Such complete systems can not only inspect for conformal coating (pre/post-cure) but also verify correct part assembly in SMT or THT applications enabling users to improve quality, real-time SPC monitoring & providing valuable yield enhancement solutions.

Figure 4. Process flows examples using Single Sided or Dual Sided Inspections.

### Different Types of Coatings

As described earlier, the quantity of fluoresced light generated by the coating & received by the camera is the critical factor to control when it comes to reliable automated inspection, and it’s usually proportional to intensity of projected UV light, UV spot size, coating thickness and or UV tracer concentration, and in order to accommodate for the variations presented in different materials and products, most of the ACI software solutions available provide different methods to adjust coating brightness and contrast between coated and non-coated areas. Main methods usually rely on flexible adjustments and combinations of camera gain, exposure time, image filtering & threshold, and those settings can be saved by system, recipe, or even down at component level. Using this pre-processing techniques, it’s fairly simple to inspect most of the commercially available conformal coatings such as Acrylic, Polyurethane, Silicon and Epoxy.

Figure 5. Different coating types (A) Polyurethane, (B) Silicone, (C) Epoxy & (D) Acrylic

### Coating Thickness Measurement

Another critical factor in conformal coating process control, is to ensure that thickness is within internal and international standards, which is typically done by non-destructive coating thickness gages. Thickness measurement is important to check the necessary protection level & may be critical in preventing long-term product reliability issues after assembly. There are several methods divided mainly into two categories, wet film measurements applied during coating application and dry film measurements made after the coating is dried enough not to damage the coating. Since most of them are manual methods, previous associated disadvantages also applies to them.

By integrating into the ACI system the existing technology of a Spectral-interference Laser Displacement Meter, a non-contact measurement device optimal for high speed in-line inspections that uses as a light source an infrared Super Luminescent Diode to emit bands of broad wavelengths that reflects between top and bottom surfaces of the coating to a Charge-Coupled Device, coating thickness measurements can be obtained across the surface of coated circuits boards and analyzed by software algorithms, ACI cameras and X-Y-Z stage. The data obtained can be utilized to apply pass / fail criteria at PCB board or component level.
Multiple thickness sensors already exist in the market using same principle but offering different measurement ranges, and since the current trend is to use thinner coatings, mainly because they let excess heat generated by surface mounts and integrated circuits to be dissipated more rapidly and with lower coating costs, optimal sensor option can be selected depending on coating application. During initial testing phase and as an example of the different options available, one of the sensors with a measurement range of 0.05 to 1.1mm & a spot diameter of ø 20µm was integrated to an ACI system and cycled over same spot on an acrylic based coating of 120 µm more than 20k times resulting in ≈ 5µm reading variation at ± 3σ, and similar results are achieved across 64, 238 & 294 µm coatings.

CONCLUSION

After successfully integrating ACI / Thickness Measurement techniques to existing AOI systems, low and high volume EMS companies can now accurately and objectively inspect and record valuable data at very high speeds, and use it to improve their process and reliability of their products.