New Opportunities for 3D SPI

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Abstract

For some years many process engineers and quality managers have been questioning the benefits of Solder Paste Inspection (**SPI**). Despite the high level of defects associated with this process, the implementation of SPI inspection has not really been adopted in many SMT lines. Many users still question the cost benefit analysis. Other users consider that the need for SPI, and especially 3D SPI, is critical during the New Product Introduction (NPI) phase or production ramp ups, but not of benefit during an established process. For them, the information provided by the SPI doesn't bring any relevant product quality improvements, OR they feel ill equipped to leverage such improvements. Clearly At this stage, we surely need to re-explore the need for 3D SPI and consider the fact that volume calculation is enough to qualify the process.

With the advanced process now demanding the use of smaller components such as 01005, µBGA or PoP's, it is clear that the use of in process inspection becomes more important and could become a standard feature to ensure quality success. In this scheme, 3D SPI will assume a more important role in the test strategy.

This paper explores the different possibilities and comes up with some new and unique solutions.

The Solder Print Process

The Solder Paste Print Process is potentially very unstable with more variation than any other SMT process. According to studies performed by numerous companies and universities this process varies by up to 60%. The reason for this variation is the large number of process parameters involved. It is generally accepted that there are about 40 variables to control. Some of these variables include, but are not limited to; paste type and formulation, environmental conditions, stencil type, stencil thickness, aperture aspect and area ratios, printer type, squeegee, print head technology, print speed, etc…

Stencil printer performance is typically quantified by measuring the Transfer Efficiency (TE)% and Standard Deviation of the paste deposition, where 100% would mean that the printed paste profile matches the calculated volume of the aperture opening. It is interesting to note that TE% varies on a typical SMT board between 20-130%.

Transfer Efficiency is generally better with rectangular apertures than square or circular apertures; although, volume variations will exist when printing rectangular apertures in either vertical or horizontal orientations. The vertical apertures will print better and with a higher volume. The worst cases for print efficiency are small squares or round apertures less than 12 mil in diameter. Also of note is how the standard deviation increases as the TE% decreases. TE% decreasing indicates decreasing volume repeatability.

It is also interesting to note that some studies show that the volume of paste across an array package may not be as important as the consistency of all the pads in an array. Such that, as long as all the pads have the same amount of paste the joints should be acceptable. However, if a few pads are under printed compared to the others in the array, then poor joints may result.

3D SPI Technology Stand Point

Like AOI (Automated Optical Inspection), the technology in terms of Solder Paste Inspection has not evolved too much over the past decade. Up to now, there were two ways to inspect solder paste, one using the methodology of laser triangulation, and the other one based on Moiré technology. Let us compare these two techniques and examine their respective advantages and disadvantages

<u>Laser Triangulation</u>

Laser triangulation technology combined with a 2D image. The height of the inspected object is given by the deviation of the laser trace (figure 1 & 2).

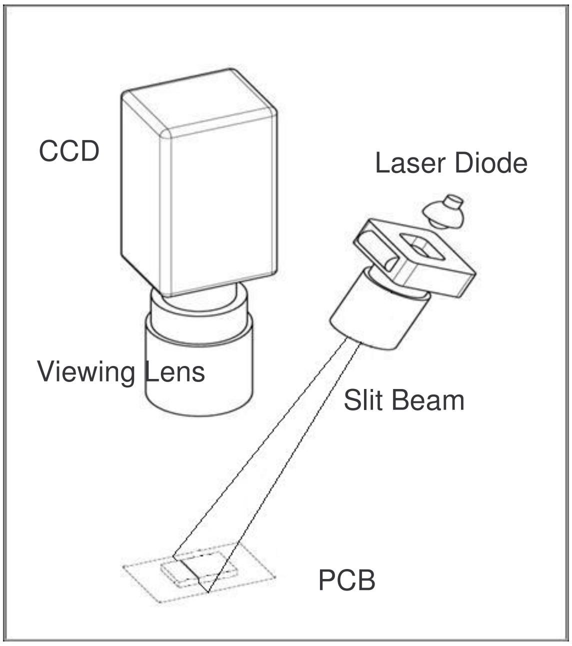

Figure 1: Laser Triangulation Methodology

Laser Triangulation drawbacks are mainly linked to the lack of resolution leading to a poor accuracy. Moreover, having only one source (one laser), the exact value of the volume cannot be calculated. This phenomenon called "Shadow effect" is due to geometrical layout of the system. The combination of single angled laser beam and camera may produce a blind spot on the opposite side of the solder deposit to the laser (Figure 2).

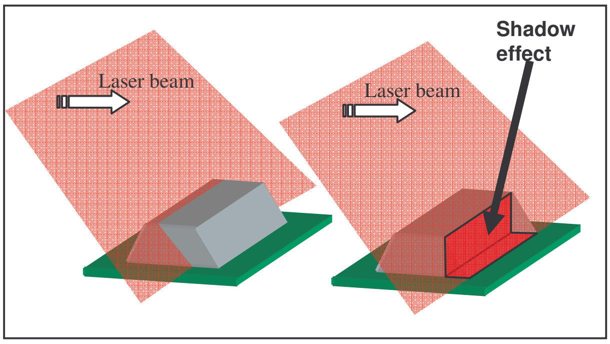

Figure 2: Shadow effect

In this area, the solder paste deposit is seen as square, as shown on figure 2, and all the quantity of paste contained in this hidden volume (red zone) is not included in the measured volume. The error in the measurement value varies from shape to shape but can be up to 48% in the case of round apertures.

Using a laser to profile solder paste on a PCB is also subject to PCB color or finish variations. It requires a lot of program maintenance when facing such variations on the production floor.

<u>Moiré Methodology</u>

Moiré topography is a method of tridimensional measurement by phase modulation. In this particular method, the lines projected on the object are modulated interference fringes, and by moving the observation grating, the height and volume of the object can be measured.

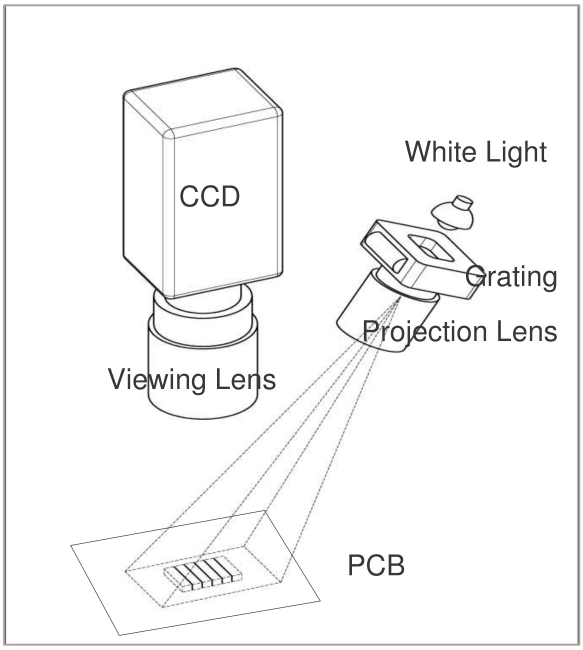

Figure 3: Moiré Methodology

The drawbacks of the Moiré methodology are the lack of depth of field of view (more or less compensated by Z movement), the influence of noise and vibration in grating process and the cycle time. The Moiré methodology is also subject to "shadow effect" if only one source of grating is used. Often, most of the systems using Moiré have 2 modes of operation, providing speed of operation at reduced accuracy using one source and providing better accuracy at slower speed using two sources.

With Moiré technology, the inspection is made of a sequence of fields of view (FOV) with individual Z-adjustment (the focus is made on average Z position in the FOV). From one FOV to the next one, covering the same array (BGA type), the references won't be the same and it may result in some differences in term of height or volume measurements. This may produce unreliable indicator of solder paste quality.

Recently, a new technology, called Flying Absolute Height Profilometry (**FAHP**), combining the best features of both methods has appeared offering an improved solution for 3D Solder Paste Inspection in term of accuracy, speed and depth of field of view. FAHP is a scanning solution using dual Moiré methodology. In other words, the board is scanned with a top down camera using 2 structured light sources (from each sides). The resulting image facilitates the calculation of both height and volume of paste eliminating the shadow effect.

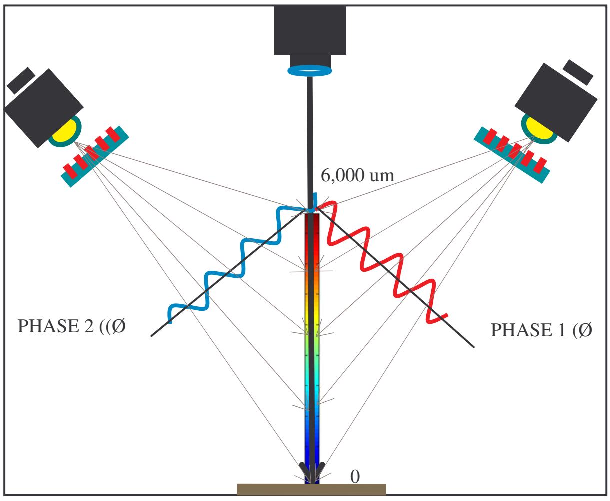

Figure 4: FAHP Methodology

This technology, with a 6mm depth of field of view, allows an accurate measurement on all type of PCB, even compensating for high warpage values. During the scanning process, the system is able to measure the PCB profile itself and compensate for the warpage over the whole board (Figure 5).

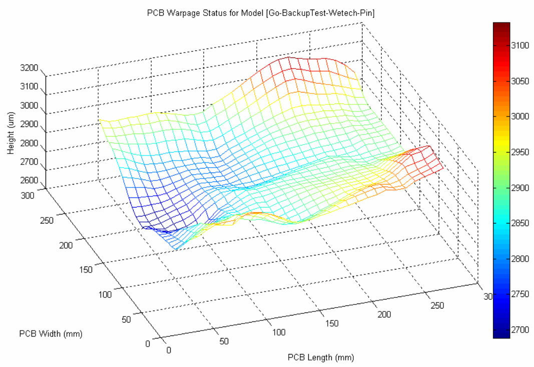

Figure 5: PCB Warpage measurement

The slope compensation (or warpage compensation), used at the pad level, provides higher height and volume accuracy (figures 6 and 7).

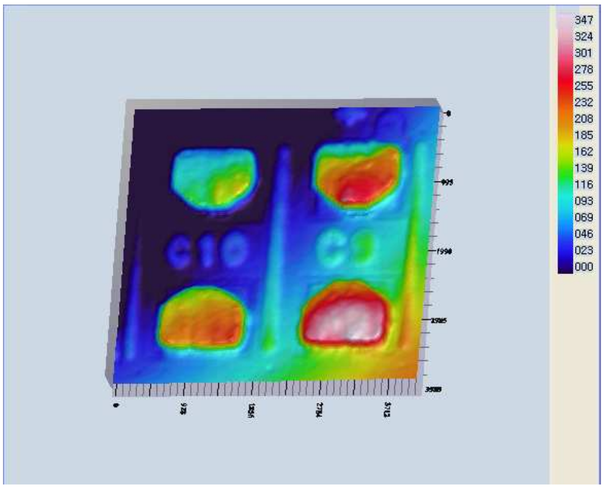

Figure 6: PCB Analysis without slope compensation

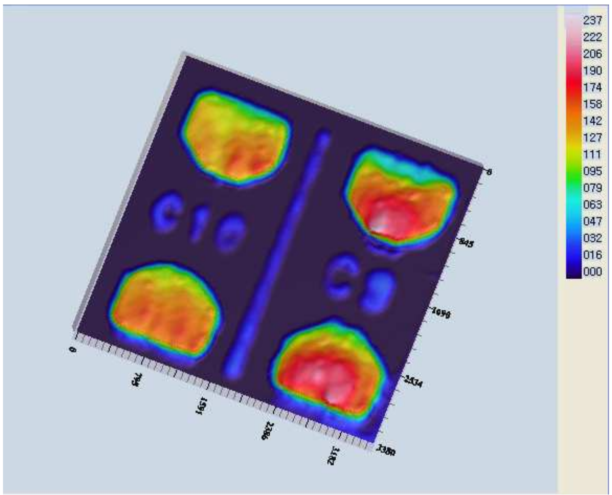

Figure 7: PCB Analysis with slope compensation

Using the "on the fly" measurement technology facilitates a continuous measurement across the PCB, the height is referenced around the perimeter of the pad without the need for Z-adjustment eliminating potential errors.

With higher reliability, less dependency on board design or color, the 3D Solder Paste Inspection, as a measurement system for small devices, will became a useful tool to control the quality of the entire SMT process. In the 3D SPI world, in order to achieve accuracy and repeatability, the measurement system has to eliminate depth of field of view and warpage problems.

Getting more from Solder Paste Inspection

Today, if most of the engineers or managers are not convinced about the value of the 3D SPI, it is surely because the current solutions are not bringing them any valuable quality data. In other words, 3D SPI systems are checking for surface, height or volume and are mainly qualifying the quality of the deposits or the efficiency of the stencil.

With wide process tolerances, volume or height measurements don't appear as key drivers in reflow process and joint quality. For example, considering an array component, BGA type, with 105 connections (figure 8), if the process window is set as [40%, 160%] for height and volume measurements, you may end up with nearly 100% difference between the max and the min in the same array.

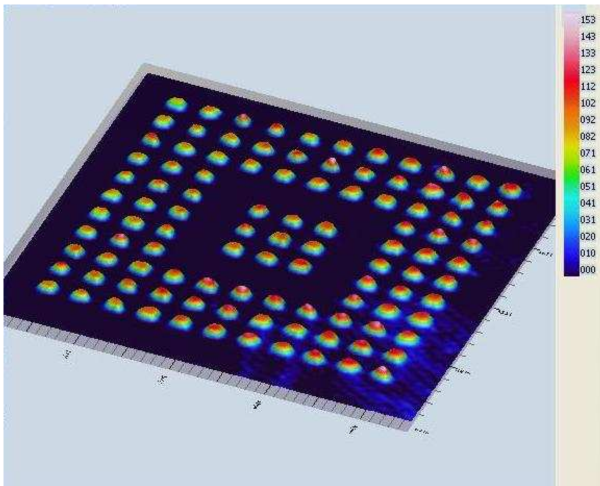

Figure 8: Height/Volume Profile on BGA (105 pads)

Considering the height values of the 105 pads and grouping them on the same graphic, the result should be a Gaussian curve centered on the average value and spread within 3 sigma. If the sigma value is low (narrow Gaussian curve), the solder paste distribution will be uniform through the array. Then, the "landing area" provided to the component will be seen as flat and will be considered as good for device placement (Figure 9).

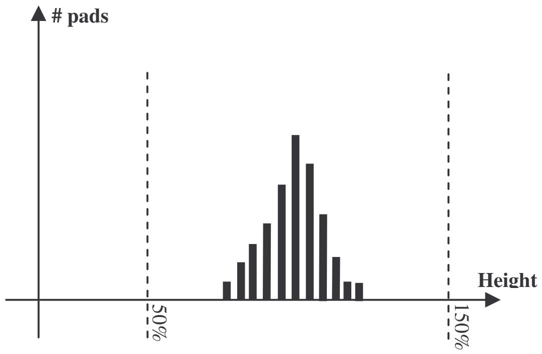

Figure 9: Height measurement distribution on BGA 105.

If the distribution is really narrow around an average value of 110% with a few pads (2 or 3) with a very low value (50%), it may lead to bad joints or opens when the component will be placed and reflowed (figure 10).

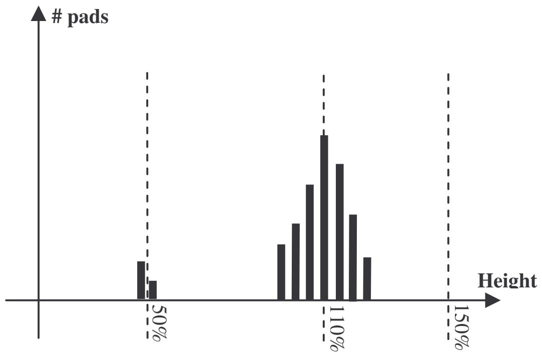

Figure 10: Height measurement distribution on BGA 105.

In this case, all the pads are individually good within the process window but the risk of poor quality is real. In fact, with a such difference between deposits, when the device is placed and pressed on the board (landing area), the contacts won't be made evenly on the entire array. Thus, the possibility to have opens in some area is real. The same phenomenon can be observed for QFP or SO type device, when the solder paste is not equally printed. In order to be able to compile these results, the 3D SPI system has to be very accurate and should not be depend of the measurement zone (warpage compensation).

In case of very small devices, such as 0201 or 01005, beside the height and the volume, the shape of the deposit has to be considered as an important driver for the final quality of the product. While placing small devices, the contact surface between component and paste has to be maximized by the mechanical pressure made by the nozzle. At this stage, the shape of the deposits is a key mechanical factor and will affect the quality of the component placement or soldering. The shape has to be controlled and flagged as a warning while the component is not placed. Then, by combining both solder paste and placement inspection, the system will be able to qualify the quality of the overall process before reflow stage.

The future of 3D SPI in Process Control

With software tools such as SPC or Closed Loop Control the future lies in integrated systems able to manage the quality of the line from a process point of view. In a practical way, more and more engineers are using SPC or are managing data from inspection tools to control their process and tighten the proess window. The current limitation of this approach is the lack of consolidation of the overall results gathered from the different inspection equipments and tests. Acknowledging that 3D SPI is bringing much more than height and volume measurements, the use of such systems will become standard tool in the SMT process.

Today, the link between solder paste volume and joint quality on individual pad has not been proven. Considering a clear link between the quality of paste deposit at the component level and the quality of the soldering process, the value of 3D SPI systems is a lot more than today. The pad to pad volume calculation or the shape differentiator, combined to pre-reflow placement inspection can guarantee the soldering process of the production line without any use of X-Ray systems which are costly and time consuming. Driving your process control and your quality by controlling every steps of the process is not impossible, it requires the ability to measure the right variables at the right process stage and consolidate them in such manner to provide relevant information. The future is in the use of the right level of inspection at the right stage and in the combination of the results.