RELIABLE THT SOLDER 3D INSPECTION BASED ON REAL MEASUREMENT DATA

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The importance of THT solder inspection is increasing. It's a phenomenon driven by a manufacturing trend that started in the mid-2010s. Still, it's something that most people haven't given much thought to until recent years because we were focused on the quality and productivity of the SMT process. The trend mentioned above refers to the increasing number of THT components on PCBs, which is driving the need for 3D inspection of THT components, especially solder joints. The problem is that today's 3D AOIs were developed for SMT inspection, which leaves THT solder inspection vulnerable.

Once, THT (Through-Hole Technology) was considered an outdated technology that slowly faded away from the mainstream of the electronic manufacturing industry. As you all know, SMT is way better at reducing product size and increasing productivity than THT. SMT is also better than THT in terms of minimizing parasitic inductance and resistance, which leads to increased performance of components and frequency of capacitors. However, the components used in THT also have advantages that excel better than SMT. First, THT parts have a higher mechanical bond strength to the PCB than SMT parts. Second, an electrolytic condenser (a type of capacitor that is used in THT) has higher absolute capacitance than MLCC (a type of capacitor that is used in SMT). Of course, MLCCs beat electrolytic capacitors in capacitance per unit area, but you'll use electrolytic capacitors if you simply need high capacity. At the product stage, these two advantages translate into high physical and electrical durability. Considering the industries that are driving the growth of electronics manufacturing in recent years are automobiles and large appliances, we can see how these characteristics are driving an increase in THT component usage. Thus, this trend is likely to continue for a long time to come, and the evolution of Automatic Optical Inspector (AOI) is changing in response.

CORRELATION BETWEEN INCREASED THT COMPONENT USAGE AND SOLDER DEFECTS

A PCB assembly process that mixes THT and SMT is more prone to problems than a single process. Due to the nature of the process, SMT and THT cannot run concurrently. Typically, the SMT process precedes the THT process, which means that THT soldering is done at the end of the assembly process. Just as SMT uses a reflow oven to solder the entire PCB at once, THT has a soldering method that is suitable for mass production, called wave soldering. This is a soldering method that involves dipping the pins of the THT components into boiling lead, which reaches a temperature of approximately 220 to 260 degrees Celsius. The problem is that this high-temperature liquefied metal can adversely affect the SMT solder on the top surface of the PCB.

Cold solder and pinhole defects tend to occur more frequently in THT than SMT, especially with the wave soldering method. Defects could be decreased by using the selective soldering method, but it'll slow down manufacturing speed, which is bad for productivity. Note that productivity issues were a big part of the reason SMT replaced THT and became the dominant production method in the first place.

In short, it is obvious that the mixing of THT into SMT increases the possibility of defects compared to traditional SMT single processes. The thing to think about here is that the reason for mixing THT and SMT is that we need products that require high reliability and safety. This means that not only process changes are increasing the probability of defects, but also the inspection standards for defects are becoming more stringent. In fact, this has been the driving force behind the rapid market expansion of 3D AOI over the past decade. However, it is still challenging to accurately perform THT solder inspection with a 3D AOI system, because current 3D AOI systems in the market have structural limitations for solder joint inspection.

A STRUCTURAL ISSUE IN THT SOLDER 3D INSPECTION

3D Automatic Optical Inspectors (3D AOIs) currently used in the electronics manufacturing industry use similar 3D technology in some form or another. There are two main techniques: laser triangulation and phase shift profilometry - commonly known as Moiré. Since both

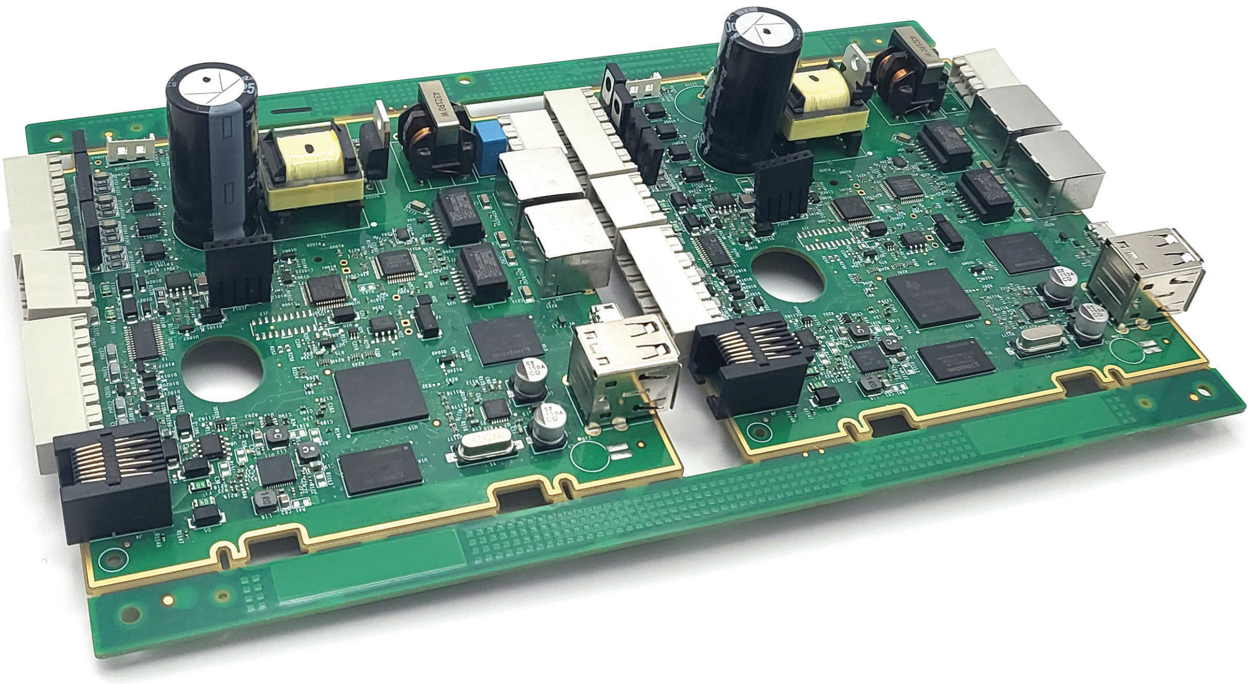
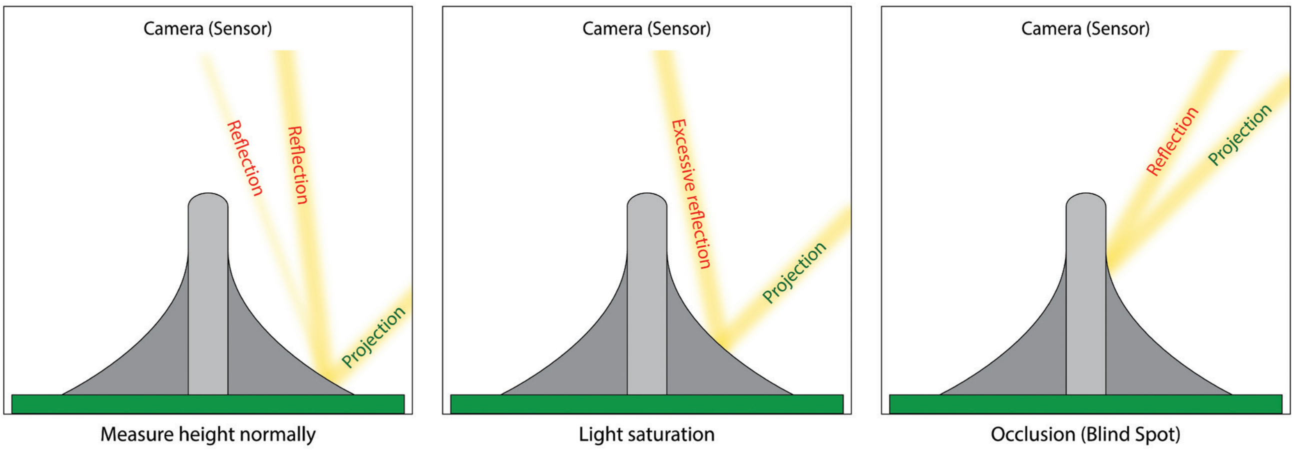


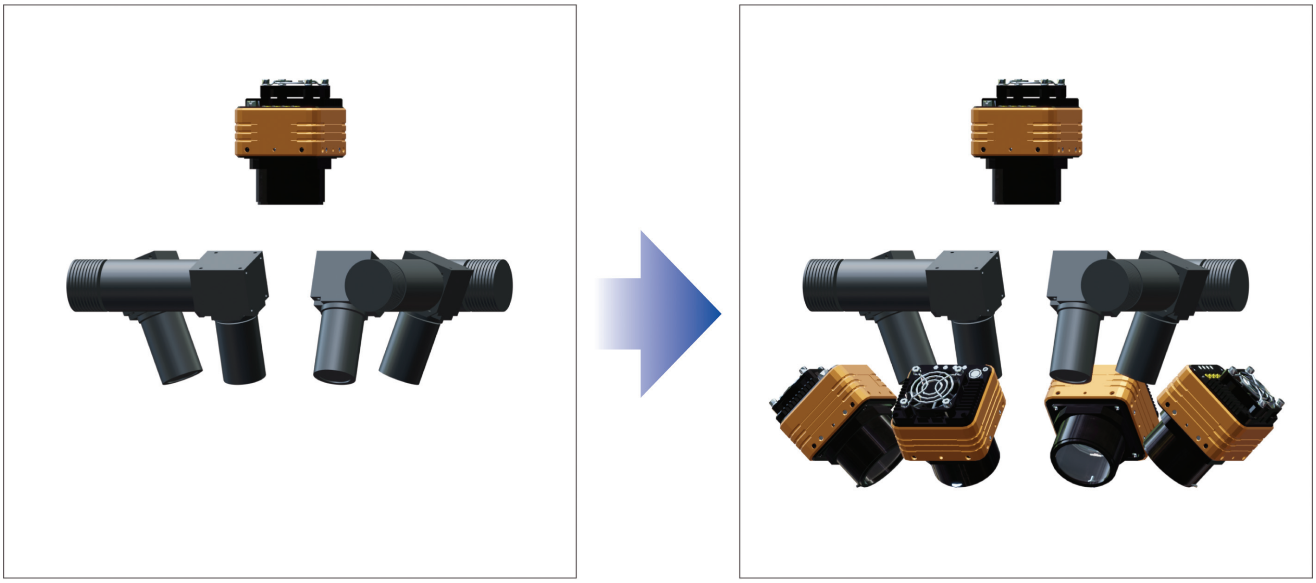
Figure 1: A THT-SMT Mixed PCB

techniques are based on triangulation, they use an optical system with cameras and projectors (or laser emitters) mounted at fixed positions to create two fixed angles. While they are a reasonable solution for fast and precise inspection compared to other 3D technologies, the fixed angle of the sensor and pattern light source means that there is a risk of measurement failure due to reflections, occlusions, etc.

Unlike 2D technology, it requires the sensor to be able to recognize patterns, which can be a limitation when inspecting reflective surfaces or objects that reflect little light. The problem with these materials can be solved by changing the color / wavelength of the light source, but the issue with angles cannot be solved in the same way. Here's a simple example to illustrate how 3D AOI properly measures the height of an object. The light from the projector (or laser emitter) must hit the object being inspected, and then the light reflected from the surface must hit the sensor of the camera. It's important to note that the projected light is specular, meaning that only a specific portion of the light reflected from the surface must be directed to the camera, not all of it. If a significant portion of the reflected light is directed at the camera, the camera is overwhelmed with too much light for it to distinguish patterns. This condition is called light saturation, which causes pattern recognition failure - i.e., 3D inspection failure. This light saturation may or may not occur depending on the angle between the projector, the surface being inspected, and the camera. Since solder joints are curved, light saturation will likely occur somewhere on the surface. There is another phenomenon besides light saturation called occlusion. Occlusion is when the camera is unable to read the projector's pattern due to gaps or obstructions. In the case of THT solder joints, the entire joint around the pins is a blind spot causing occlusion. SMT solder joints also suffer from this issue, but with a key difference: in SMT components, the solder joint is only on one side. In contrast, THT components have a blind spot that encompasses the entire 360-degree area around the pin.

Figure 2: Cases of THT solder joint measurement





Optical system of traditonal 3D AOI

Optical system of the ART

Figure 3: Evolution of optical system of 3D AOI

Whether it's light saturation or occlusion, it has the same result in that we don't know the height of the point where the problem is occurring. In 3D inspection, if this happens, it will show up as noise in the form of a hole or a spike upward in the area, which means that if the measurements are correct, the THT pin solder joint should show up in the 3D image as a hollow area around the pin rim. However, you probably won't see this on your equipment under normal configurations because 3D AOI manufacturers are already aware of this optical limitation and use 3D algorithms to restore the void in those areas. The problem is that if you have a hole in a slope where light saturation occurs or a cold solder crack in the rim of a fin, a typical 3D AOI algorithm might fill it in using the algorithms. In products that require high reliability, this can be catastrophic.

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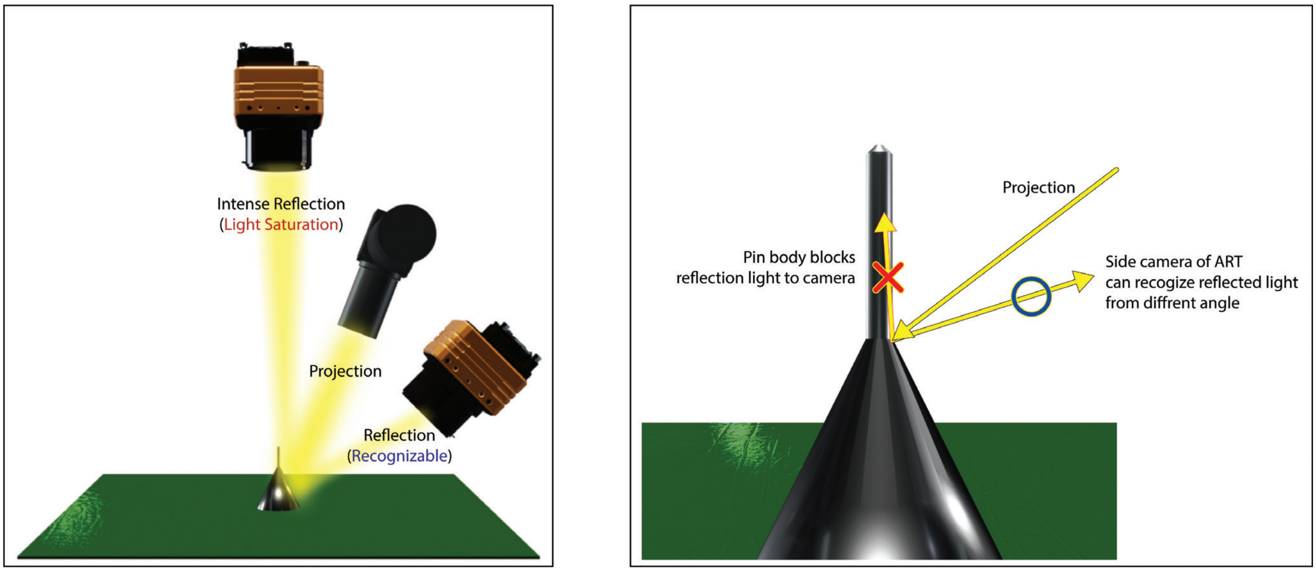

Concept of Anti-Reflection

Concept of resolving occlusion issue

Figure 4: Conceptual images of advantages of the ART system

Figure 5: The ART

Simply put, triangulation-based technologies can sometimes be problematic for inspecting non-flat materials with reflective surfaces, such as solder joints. Nevertheless, Moiré and laser scans have become the mainstream of 3D inspection technology because, even with their weaknesses, they are the only measurement method that meets both inspection performance and productivity. Technologies like white light interferometers and confocal chromatic sensors are precise, but they are expensive, slow, and have a small measurement area. Depth variation technologies are also too slow for mass production systems. Technologies only based on triangulation, especially Moiré and laser scan, meet the current requirements of electronics manufacturing in terms of cost of acquisition, inspection speed, inspection quality, and measurement range. Therefore, changing measurement techniques because of weaknesses in triangulation is not a viable option. Rather, it is needed to improve triangulation-based techniques to overcome these weaknesses. The good news is that MIRTEC has a solution to do that.

3D TECHNOLOGY FOR THT SOLDER JOINT INSPECTION BASED ON ACTUAL MEASUREMENTS

With a single solution, MIRTEC has solved both of the THT solder joint inspection problems that can occur with triangulation-based technologies. Since the initial development of the technology was to overcome the reflection problem, the technology is named Anti-Reflection Technology and the equipment that uses it is called the ART. We noted that both above issues are ultimately caused by the fixed angle between the projector and the sensor. This means that an optical system configured with an additional measurement angle can avoid these issues.

A typical 3D AOI consists of a main camera with a top-down orientation and multiple projectors with fixed angles. For laser scanning systems, the projectors are replaced by one or two laser emitters, but the configuration is similar. Depending on the equipment, the position of the projectors and camera may be reversed, but the fact that there is essentially only one projector and camera angle remains the same. In the case of the ART developed by MIRTEC, the optical system is composed of additional cameras with a different angle than the existing camera. Since the most standard and efficient form of existing optics is a moiré system with one top-down camera and four digital projectors, we configured the ART as a five-camera system. Those familiar with the traditional side camera option here will recognize the similarity to the ART in terms of structure. However, there is one very important difference between the cameras added in the ART compared to the optional side camera. The side camera in the ART has the capability to do a 3D inspection. The side camera option in the original 3D AOI is a secondary, lower-performance camera that is not capable of accurately reading 3D patterns.

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The principle by which ART solves reflection and occlusion is the same. In the case of light saturation due to reflections, a large amount of light reflected to the top camera means that less light is reflected in the other direction. Therefore, if you observe the projection pattern from a different direction than the top-down camera, you can make 3D measurements normally without suffering from light saturation. Therefore, by constructing 3D data from the patterns measured by the ART's side camera and the patterns measured by the top-down camera, and then merging the two data sets, normal THT solder inspection is possible without artificial data fill-in or measurement errors.

In the case of occlusion, it occurs because the light reflected by the projection light from the pin and solder of the THT component is blocked by the pin itself and cannot be directed to the top-down camera. Therefore, as with the reflected light problem, normal data can be obtained by merging the pattern data observed by the side camera with the observation results of the top camera. If there is a crack in the area due to a cold solder defect, a typical optical system would run the risk of the 3D algorithm filling in the data and deciding that the crack is normal (underkill). On the other hand, the ART does not have such kind of issue. We can prove it of course. Please refer to figure 6 below.

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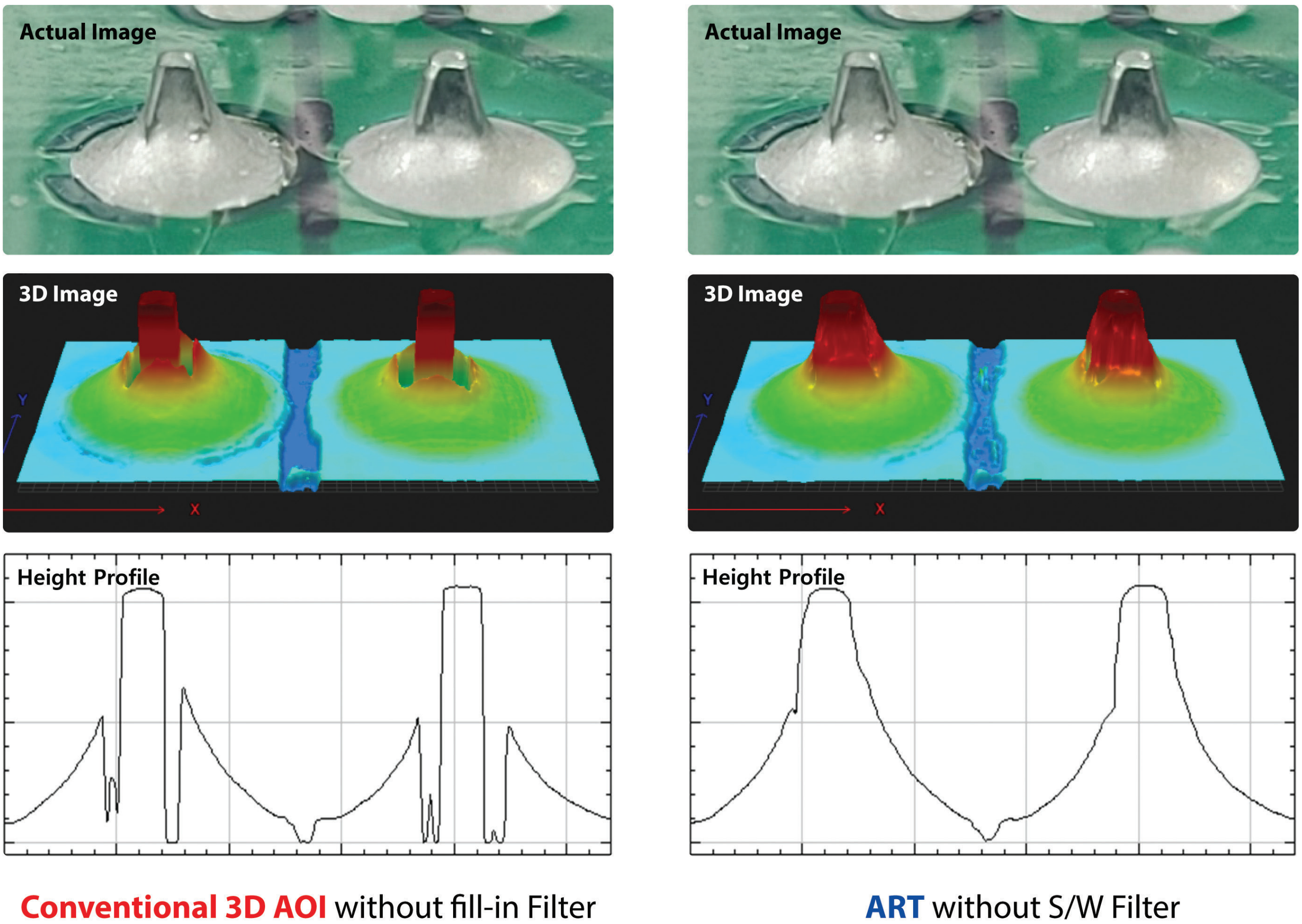

Figure 6: THT solder joint measurement results comparison - based on actual acquired data

CONCLUSION – THE BEST OPTICAL TECHNOLOGY AVAILABLE FOR THE BEST QUALITY CONTROL

Defects occur even in the most precisely designed manufacturing processes. The more complex the process, the more areas of failure. And when you mix two different PCB assembly methods, it's no surprise that you need to pay even closer attention to the quality than before. This is especially true if the reason for mixing THT components into SMT products is to ensure product reliability and durability. Therefore, those who manufacture these products need to have a solution to properly detect when defects occur.

MIRTEC has developed such a solution and is confident in its performance. We invite anyone who has read this far to contact us if they are interested or have any doubts. Because we are ready to prove it.

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