A multiple inspection strategy

improves detection without increasing false calls.

Traditionally,

AOI can be deployed in three areas of the SMT process:
post-paste print, pre-reflow and post-reflow. The rationale of putting AOI early in the process is the belief of early defect detection and repair; the earlier in the process a defect is detected, the lower the repair cost. Fixing a solder paste defect is much easier and therefore less costly before reflow than after reflow. The problem with this line of thinking is that defects are produced throughout the assembly process, not just in the beginning. Component defects can be detected only after components are placed; defects such as bridging and tombstoning can be detected only after reflow. If the AOI is used upstream only, it will miss many of the defects. Since the majority of 01005 defects are bridging and tombstoning, post-reflow AOI is essential for ensuring product quality.

For assemblies using 01005 components, the post-paste print AOI serves mostly as a process monitoring tool because, short of scraping a poorly printed bare board, there is no effective inline repair mechanism for random paste defects. Any manual manipulation tends to introduce more problems than it can fix. Pre-reflow inspection is a good process monitoring tool for verifying component placement, but again, it is not feasible to attempt inline repair of misplaced 01005 components. It has been shown that 01005s self-align during reflow. For example, research by Flextronics showed that 01005 placement could be off by as much as 45 µm and maintain component alignment.[1] Other work by Cookson showed 01005s will self-align despite a theta offset as large as 25°.[2] The tendency to self-align and the difficulty and risk of pre-reflow repair render pre-reflow AOI inspection nothing more than a process monitoring tool.

Offline repair and rework equipment for 01005 assemblies are available today. They can repair most types of defects that can occur on a 01005 assembly. However, offline repair is expensive.

The best inspection strategy for 01005 assemblies involves the use of multiple AOIs in multiple points of the SMT process to monitor the process and detect defects. Since repair is not always feasible, the upstream AOI needs to be able to pass defect data to the downstream (post-reflow) AOI so that additional verification can be performed on the suspected components. This will increase detection without increasing the false call rate.

Essential AOI Capabilities

Various characteristics of AOI machines are essential for 01005 inspection. Let’s look at a few of them in detail.

High magnification. Comparing and evaluating AOI equipment from different vendors can be a confusing process. Some of the specifications of interest are analogous to those considered when shopping for a handheld digital camera. The imaging sensor type and pixel count (megapixels), as well as the optical and digital magnification (zoom) are important features that can help determine the ultimate capabilities of the system. To accurately inspect an 01005 device, it is important that the combined optical and digital magnification be sufficient to provide the necessary amount of resolution and information to the AOI software inspection algorithms. However, more is not necessarily better. Higher magnification leads to a smaller field of view (FOV) and therefore longer image acquisition times and more data to process. As cycle times shorten, the AOI must balance magnification and image acquisition speed.

One of the most popular AOI specifications to determine 01005 inspection capabilities is the pixel size. The pixel size is determined by the properties of the imaging sensor and the optics of the AOI system. Take, for example, a typical 1.3 Mp CMOS sensor with an array size of 1280 x 1024. Fitted with a lens at a focal distance that produces a field of view of 32 x 25.6 mm produces a pixel size of 25 µm. Considering that an 01005 resistor is 200 x 400 µm, the projected image of the component would be 8 x 16 pixels in size. This may not be enough information for the inspection algorithms to provide sufficient defect detection. However, the same sensor with a lens that provides a field of view of 16 x 12.8 mm results in a pixel size of 12.5 µm, which would display the component at 16 x 32 pixels. This four-time increase in area may now be enough information for the inspection algorithms to accurately detect the defect conditions.

When selecting an AOI for 01005 inspection, it is important to find the balance between resolution and inspection speed. Some systems feature multiple cameras at different magnifications that permit the high magnification necessary for accurate 01005 inspection, while maintaining a fast cycle time by using the lower magnification camera for other larger components. In this way, the system is flexible enough to handle a range of product types without hardware modification.

High positional accuracy. As component size gets smaller, the manufacturing process equipment accuracy becomes critical. If a placement machine is inaccurate, then 01005 component defects will be unavoidable. However, whereas a placement machine is an essential part of the assembly process, the AOI machine is a supplement. Having an inaccurate AOI system would not prevent the product from being assembled, but if it cannot identify positional defects, then the inspection data may be useless. As a rule-of-thumb, the AOI system should have sub-pixel accuracy (**Figure 1**). This will ensure the system is sufficiently accurate to detect small deviations in position that can lead to an 01005 defect.

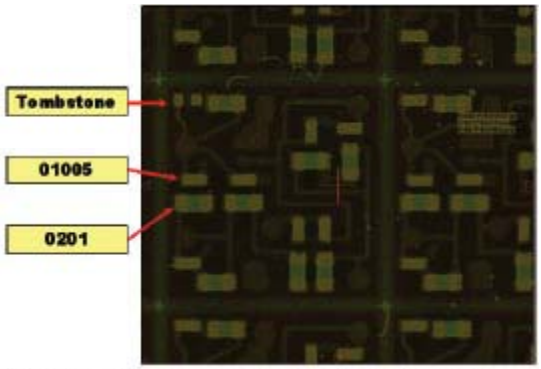

Figure 1. For 01005 inspection, the AOI system should have sub-pixel accuracy.

Programmable lighting to highlight defect. In any machine vision application, lighting is an important feature. Magnification of the object under test is only half of the equation. The second half is whether the defect condition can be identified under the current lighting condition. Trying to find one light source that will enable detection of all defect conditions is nearly impossible, given the ever-changing environment of electronics manufacturing. To ensure the widest defect coverage for today's component and PCB configurations, as well as those to come, a dynamic light source is crucial. With the reduction in cost of light-emitting diodes, AOI equipment manufacturers are able to configure light arrays that are highly customizable within the inspection software. With multiple colors at various angles, the AOI programmer has the flexibility to enhance the contrast of the image to easily identify a multitude of defect conditions (**Figure 2**). Even within the 01005 component family, there are many variations of color and surface properties. Combine this with the variations of paste composition, pad size and material, and PCB color and texture, and the possibilities are endless. Programmable lighting is an invaluable tool for ensuring the widest range of defect detection.

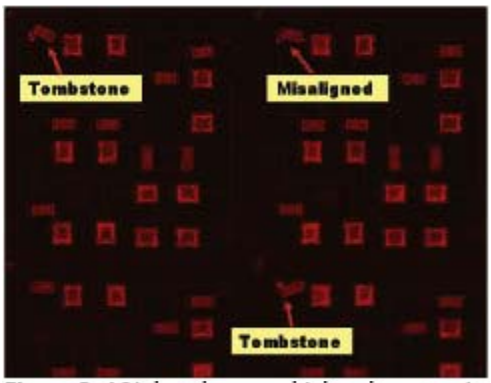

Figure 2. AOI that shows multiple colors at various angles has the flexibility to enhance the contrast of the image to easily identify many defects.

Tele-centric lens to reduce false calls. For increased accuracy and repeatability and extremely low false call rates, the use of tele-centric optics has become increasingly popular in AOI equipment. Normal lenses exhibit varying magnification for objects at different distances from the lens. This causes several problems for machine vision and other applications:

- The apparent size of objects changes with distance from the camera.
- Some features or objects may be hidden by objects closer to the lens.
- The apparent shape of objects varies with distance from the center of the FOV. Objects appearing close to the edges are viewed from an angle, while objects near the center of the FOV are viewed frontally. (Circles near the center of the FOV become ellipses when moved toward the periphery.)

Tele-centric lenses, on the other hand, have the same magnification at all distances. An object-space tele-centric lens creates images of the same size for objects at any distance and has constant angle of view across the entire field of view. An object too close or far from the lens may still be out of focus, but the resulting blurry image will be the same size as the correctly focused image would be.

Because their images have constant magnification and geometry, tele-centric lenses are used for metrology applications, when an AOI system must determine the precise size of objects independently from their position within the FOV, and even when their distance is affected by some degree of unknown variations.

Network capable software to share defect information. One important function of an inline AOI system is data collection and retrieval. These data can be in the form of a text output, database, image collection, or combination of several formats. Collecting the data is a basic function of most AOI systems and can be as simple as enabling a checkbox in the software. However, retrieving the information can be a little more complex and depends on the configuration of the manufacturing line.

In a networked environment, the AOI can simultaneously inspect a PCB while transmitting results from the previous assembly to a "downstream" review/rework station. The downstream station is then not only communicating with the AOI system, but also storing inspection results and review operations into a SPC database. Inspection results can be viewed in real-time or archived for later review.

Repair station, offline programming and SPC software are common network tools often sold as options by AOI vendors. One new feature takes even greater advantage of the network environment of the manufacturing line. By placing multiple AOI systems in a single line, inspection results can be shared to actively affect the inspection or review at each stage. This new feature introduces a more dynamic inspection technique to ensure the highest possible defect detection.

Since the 01005 assembly line lacks a feasible inline repair mechanism, the post-reflow AOI needs to be able to use the inspection data from the upstream AOI (or AOIs) to enhance its defect detect-ability. In other words, they need to be able to collaborate to achieve the best possible inspection. For example, a defect such as insufficient solder is most effectively detected by the post-paste AOI. It is more difficult for the post-reflow AOI to detect this defect without generating false calls. By combing the defect reports from the upstream AOIs, the post-reflow AOI can ensure the defect will not escape detection. In an ideal situation, three AOI machines are on the line. The post-paste AOI should be tuned to detect stencil misalignment and insufficient solder; the pre-reflow AOI should be tuned to detect component defects such as missing or polarity, and the post-reflow AOI should be tuned to detect bridging and tombstone defects. Optimal detection can be achieved by dividing the tasks and combining results.

With the continuing miniaturization trend, the 01005 is sure to become more popular. Equipment manufacturers must provide machines not only capable of handling these devices, but flexible enough to be ready for what lies beyond. AOI has evolved significantly over the past decade and has proven its efficiency in detection capabilities is well beyond that of human inspection. The key to yield enhancement of an 01005 assembly process is careful implementation of AOI.

References

1.Fredrik Mattson et al, "PCB Design and Assembly Process Study of 01005 Size Passive Components Using Lead-Free Solder, SMTAI, September 2004.
2.Chrys Shea et al, "A Feasibility Study of 01005 Chip Components In A Lead-Free System," SMTAI, September 2005.