研究自动光学检查（AOI）是困难的，因为过程变量太多，而并非所有元件均可用于无铅过程。但是，本文将在这些研究中探讨在线AOI的优点，以及过序本身，包括保持元件在公差范围内的布局、检查焊膏的涂敷以及检验焊点。过程的任何变化总是要求对结果的密切监视。应使用SPC确定最佳设定值并保持对过程的控制。AOI不能监视烘箱温度，但能记录其影响的结果。AOI还能记录全部结果，这样就可以同所有其它过程参数记录对比。

Controlling Pb-Free Processes through AOI

Thorsten Niermeyer

Allocating test resources during qualification will reveal which method is optimum for new soldering processes.

AOI is an established in-line or offline tool for the verification of screen print, component assembly and solder joint integrity. Depending on product requirements, AOI can be deployed in various positions in the SMT line. AOI typically uses visible light and cameras to acquire images of the (partly) assembled PCB and deploys algorithms to verify the correctness of the product. This technology has enabled many different applications of AOI, such as paste inspection, pre-reflow component inspection, and post-reflow or post-wave joint and component inspection.

Early in the discussion on lead-free, AOI vendors were asked about their ability to handle lead-free alloys. The U.K.-based National Physics Laboratory invited AOI suppliers to participate in a comparison study. The study was carried out on a purpose-designed test board with a broad spectrum of defects using a no-clean 95.5Ag3.8Cu0.7 alloy. Results of this comprehensive study of six AOI systems were published in 2002.[1]

The results showed good individual defect coverage and general capability to handle the technology: "Thus the overall conclusion from this work must be that automatic optical inspection of lead-free surface mount assemblies presents no more challenges than would SnPb assemblies. Indeed, current programmes developed for SnPb assemblies could be adapted to work for lead-free assemblies with some changes in the accept/reject values."[1] The nonbiased report offered important confirmation for companies investing in AOI technology.

Since then, lead-free has been adopted in the manufacturing environment. Some SMT manufacturers have converted more than half their assemblies. And there have been learning curves for both the AOI vendor and assembler.

AOI has proven effective in identifying differences in the appearance of solder joints, but what about other defects? The defect spectrum remains the same, but the pareto of defects has shifted.

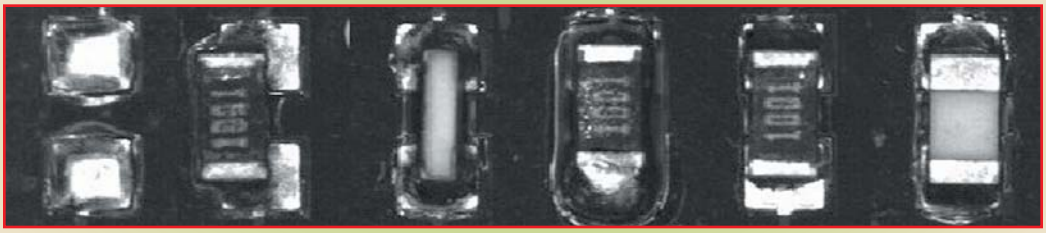

FIGURE 1: Examples of 0603 defects on a lead-free PCB.

When inspecting the defects, has nothing changed?

It is correct to say that a billboarded chip looks the same, as does an insufficient solder joint (**Figure 1**). But lead-free components compel certain layout changes, such as making pads smaller and closer to the components, to avoid tombstoning. If AOI is used post-reflow, the elements for defect detection are static, other than these smaller solder joints. Smaller size poses its own challenges, such as resolution and visibility of the joint. But AOI can also verify if the joint has excess solder (**Figure 2**); too much paste could be a result of smaller pads soldered with the same paste thickness. Excess paste could cause other problems that may not be detected immediately, such as solderballing.

If AOI were used in the pre-reflow position for process verification, it would have to be able to detect the offset component with smaller tolerances. These limits could be as small as 70 µm for a 0402 component. The AOI system must cope with these small dimensions in a reliable, repeatable manner. AOI machines typically have no issues measuring components in either SnPb paste or lead-free alloys. The differences in the look of the paste are minor; the major differences are the design and tighter tolerances of the lead-free environment. An accurate pre-reflow AOI can return precise measurements of assembly quality and process variation and provide statistical feedback about the process capability (Cp and Cpk values). These are the best indicators for maintaining tight control over manufacturing processes.

Whether lead-free solder joints appear duller very much depends on the alloy used (specifically, the bismuth content) and at what "age" the solder joint is viewed. Immediately after reflow, joints still appear bright and shiny. Boards that are a few weeks old typically appear to have lost shininess, more so than their tin-lead equivalents. This would theoretically require a change of test parameters for AOI, but boards are not inspected a few weeks after manufacturing. High-end AOI systems use more sophisticated methods that are not built upon reflection factors but rather geometrical shape analysis through 3D inspection.

FIGURE 2: AOI systems can identify excess solder conditions that can occur in smaller pads, which are typical in lead-free designs.

When inspecting lead free, give careful consideration to all parts involved in the process. This includes components with lead-free leads. Does the tin-lead finish of a component lead contaminate the solder joint and influence its look? If so, by how much? Is the approach to qualifying lead-free manufacturing a scientific one, or does it involve taking currently available parts and ticking a box for future requirements?

The Role of AOI

Manufacturers qualifying SMT processes for lead-free capability typically include only their in-line test equipment in the study. Such studies have primarily focused on the manufacturing part of the process, mostly screen printers and ovens. If an in-line AOI were in place, depending on the volume of boards produced, a test program would have been developed. When starting with a new process and technology, however, all the capabilities available to track changes and record results should be used. This includes offline test equipment as well as x-ray systems, which are designed to take a closer look at solder joints and analyze their structure – including hidden joints (BGA, CSP) – and report on voids inside the joint. To detect all deviation, and to permit the eventuality that new problems will arise, deploying the maximum test during a qualification phase is important.

Little focus has been given to the fact that an in-line AOI system could be used for statistical process improvements, or to record defects correlating to process alterations. In-line AOI is the ideal detection method for deviations, provided tolerances are tight. On a smaller batch of boards, users can afford to have a higher level of calls by the system that need to be verified and confirmed by process personnel. These tighter tolerances also lead to earlier detection of process variations and guide systems engineers to optimum settings on manufacturing and AOI equipment.

Any process change always requires close monitoring of the results. SPC should help identify optimum settings and prevent the process from drifting out of control. Even though AOI cannot monitor oven temperature, it can record results of the effect. The most valuable contribution of an in-line AOI system for lead-free processes is the capability to record all results, which in turn permits comparisons with the log of all other process parameters. Taking careful note of all test results during the qualification phase is permits comprehensive review of the experiment later.

The biggest change expected with the transition to lead-free soldering is the quality of the solder joint – the electrical and mechanical connection between the PCB and the component. This justifies spending as much effort on test equipment as on manufacturing equipment. The overallocation of test resources is not intended for the settled stage of the process, but rather the qualification phase to determine which resources to deploy during the later stage. Only the allocation of a maximum of test methods during the qualification phase will identify the optimum test method for the new process. ■

References

1. NPL Report MATC(A) 119, "A Comparison of Automated Optical Inspection Systems For Use With Lead-Free Surface Mount Assemblies," July 2002.

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