PCB and Assembly

Justifying AOI and Automated X-Ray

By Don Miller, YESTech, Carlsbad, CA

Two of the guiding philosophies for the implementation of test and inspection technologies are prevention and detection. Prevention places the priority on process control and elimination of defects by implementing corrective action. Detection focuses inspection efforts on ensuring that no defective assemblies escape from the factory floor.

Different inspection goals will dictate the need for process information at varying levels of detail. Having a well-understood set of goals helps ensure that the selected technologies can be used to maximum benefit.

A comprehensive test and inspection strategy often will use a combination of automated optical inspection (AOI), automated X-ray (AXI), in-circuit test, and functional test to ensure inspection coverage and yield rates are maximized. The sum of results from multiple inspection techniques far outweighs the capabilities of any one system alone. In addition, the process can be streamlined by delegating the inspection duties of the equipment to what it is best suited for, eliminating total dependency on any one method.

With improvements in inspection technology come enhanced defect analysis and ultimately more accurate data. Although data collection is a critical aspect of process improvement, to ensure the process remains in control, you also must enforce a plan that provides immediate feedback.

The benefits of this plan are quickly realized by minimizing the response time and cost caused by a process anomaly. AOI and AXI systems can address multiple tasks in various locations of the manufacturing process and have become the leading technologies in the quest to identify defects and improve process yields.

Automated X-ray inspection system YTX-X3 can provide 3D imaging.

Automated Optical Inspection

When comparing the speed, efficiency, and flexibility of AOI to other test and inspection methods, the benefits are clear. For example, a typical manufacturing line may use two to four inspectors to visually identify and repair component and solder defects. In contrast, an AOI system requires only one operator to detect and repair defects as well as collect all necessary data for yield improvements. This can either reduce the per-shift requirement for labor or enable reallocation of resources to another part of the manufacturing process.

Because AOI systems can be placed in various in-line and off-line configurations, it is important to thoroughly analyze the factors that influence the overall yields to determine the best fit for your process.

A return-on-investment model is an excellent tool for estimating the benefits of the AOI system in different process configurations. The goal of this exercise is to reduce the cost per function and improve the current yield rates.

If the main objective of your plan is to deploy a better defect detection system, then placing the machine at the end of the manufacturing line or in an off-line loca-

tion will be best for your model. If you are more interested in defect prevention, then you will want to insert the AOI system farther upstream in the process.

Depending on individual requirements, the best results could be achieved by placing the machine at one or more of these locations: post-print, pre-reflow, or post-reflow. In any of these scenarios, the reduction or reallocation of labor is of particular interest, especially when considering research has shown that, on average, human inspection is only approximately 50 percent efficient when detecting visible defects on PC boards.

There are many factors behind this inefficiency, but it is primarily the repetitive and demanding nature of the work that makes concentration difficult to maintain. The monotony also can result in a high staff turnover with consequent costs in hiring and training personnel.

In contrast to human inspection, AOI delivers both accurate and repeatable results. In many installations, it has been tested with efficiency as high as 99 percent.

Various characteristics of AOI systems are essential for today's inspection requirements.

Magnification

Pixel counts and optical and digital magnification are important criteria that often determine the ultimate capabilities of an inspection system. To accurately inspect small devices, such as 01005s, the combined optical and digital magnification must provide the necessary amount of resolution and information to the AOI software inspection algorithms.

But, higher magnification leads to a smaller field of view (FOV) and longer image acquisition times and more data to process. As cycle times shorten, the AOI system must offer a balance between magnification and image acquisition speed.

The pixel size is determined by the properties of the imaging sensor and the optics of the AOI system. For example, a typical 1.3-megapixel CMOS sensor has an array size of 1,280 x 1,024 fitted with a lens that produces a field of view of 32mm x 25.6mm, which has a pixel size of 25µm. If you consider that a 01005 resistor is 200 x 400µm, the projected image of the component would be 8 x 16 pixels.

This may not be enough information for the inspection algorithms to provide sufficient defect detection. However, the same sensor with a lens that has an FOV of 16 x 12.8mm results in a pixel size of 12.5µm, which would display the component at 16 x 32 pixels. This 4X increase in area now may be enough information for the inspection algorithms to accurately detect the defect conditions.

Optics

For increased accuracy and repeatability, the use of telecentric optics has become increasingly popular in AOI equipment. Traditional lenses exhibit varying magnification for objects at different distances from the lens and can show the apparent shape of objects changing with distance from the center of the FOV. Telecentric lenses have the same magnification at all distances. An object-space telecentric lens creates images of the same size for objects at any distance and has constant angle of view across the entire FOV.

Because their images have constant magnification and geometry, telecentric lenses are useful 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.

Programmable Lighting. In any machine vision application, lighting is critical to achieving the desired results. 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 component and PC board configurations, a dynamic light source is crucial. With the reduction in cost of light-emitting diodes, AOI equipment manufacturers can configure light arrays that are highly customizable within the inspection software. With multiple colors at various angles, AOI users have the flexibility to enhance the contrast of the image to easily identify a multitude of defect conditions.

Even within a given component type, the possibilities are endless. There are many variations of color and surface properties along with the variations of paste composition, pad size and material, and PC board color and texture. Programmable lighting is an invaluable tool for ensuring the widest range of defect detection.

Positional Accuracy. As component size decreases, the positional accuracy of both manufacturing and inspection equipment becomes critical. As a rule of thumb, the AOI system should have subpixel accuracy. This will ensure the system is sufficiently accurate to detect small deviations in position that can lead to a 01005 defect.

Network-Capable Software

Two important functions of an AOI system are data collection and retrieval. The data can be in the form of a text output, a database, an image collection, or a combination of several formats. Collecting the data is a basic function of most AOI systems; however, retrieving the information often is more complex and depends on the configuration of the manufacturing line.

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

While most automated test equipment is designed for post-reflow or end-of-line inspection, an AOI system can be implemented almost anywhere within the process. This flexibility
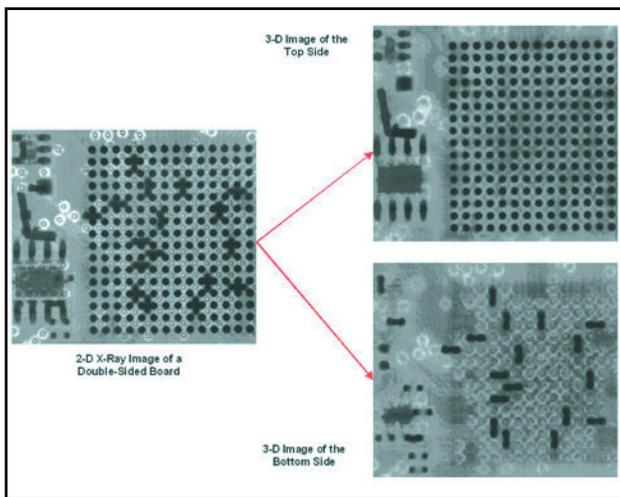
Tomosynthesis slice analysis (3D imaging).

allows the overall inspection plan to be fine-tuned by moving or adding AOI equipment to different manufacturing line locations until the desired yield is achieved.

Automated X-Ray Inspection

AXI is becoming increasingly popular because, like AOI, it is a noninvasive inspection solution that provides real-time process data and can be used effectively for defect detection and yield improvements. X-ray images of solder joints can be analyzed automatically to detect structural defects such as insufficient solder, voiding shorts, opens, and other defects that can account for upwards of 90 percent of the total defects on a complicated board. But unlike AOI, X-ray imaging is not hindered by hidden solder joints, component shields, and high-density double-sided boards.

This key advantage of inspecting hidden solder joints makes AXI the logical choice for inspecting complicated boards, especially ones with BGAs, CGAs, CSPs, or components that are under RF shields. This is a critical advantage of AXI, since a large number of boards fall into this category with the increasing popularity of array-style packaging. In addition, many cell phones and wireless communications products involve placement of RF shields over unsoldered components at pick-and-place, using the reflow processes to solder them to the board.

AXI can be useful at many stages of the assembly process, but time and resource constraints usually limit most products to a single X-ray inspection. For that reason, it should be implemented where it will provide the maximum benefit to the process.

Since automatic analysis of finished solder joints is AXI's strength, most systems are placed after the solder process — whether it's wave or reflow. At this point, all solder joints on the board are present and can be covered in a single test. Also, by waiting until the completion of the assembly process, any other defects such as damaged or missing components will be detected.

AXI Types: 2-D or Transmission X-Ray

With the 2-D technique, X-rays are generated at a fixed-point source, pass through the PC board assembly, and form an image on an electronic detector. The image is converted into a digital image and transferred to a computer where the analysis takes place. This technology is widely used for single-sided boards in automotive and other high-reliability applications.

Advanced image processing software now is available to distinguish components and conduct automated inspection of solder defects. Transmission X-ray is the most common form of X-ray inspection for electronic assemblies.

3-D X-Ray

3-D X-ray technology provides clear images of single layers or slices of the board to facilitate unimpeded inspection of double-sided boards in a single pass. The laminographic 3-D technique requires the X-ray source and detector to move in a circular pattern 180° out of phase. Only features in one plane are in focus, and components and solder joints not in the plane are sufficiently blurred out.

The tomosynthesis technique creates 3-D images by reconstructing multiple transmission images taken from different angles. These images are digitally combined to create slices at any depth. Both techniques are commonly used today in X-ray inspection applications for more complicated

double-sided electronic assemblies.

A historically critical challenge for AXI systems has been to accurately identify defects within the allowed cycle time. To maximize throughput and defect coverage, some systems today permit selective 2-D or 3-D inspection on the same assembly. Specific components or regions of interest can be selected for 3-D inspection without significantly impacting overall inspection time.

Another recent development is the portability of data between AXI and AOI systems from some suppliers. The capability to share libraries, inspection programs, and SPC data between AOI and AXI systems can great-

---

In-line or off-line review stations can convert inspection results into an efficient rework process by identifying the defective areas of assembly....

---

ly enhance machine usage and defect coverage. The flexibility of today's AOI and AXI systems extends beyond placement within the manufacturing process. There has been a steady progression in performance and usability since such machines were first introduced in the early 1980s. Initial versions were very expensive, limited in capability, difficult to program, and required many hours or days for the creation of and maintenance of inspection programs. Unless running in a high-volume, low-mix production line, it was difficult to cost-justify these technologies as a viable solution.

Because of the rapid evolution of hardware and software technologies, the latest generation of AOI and AXI systems has overcome most of these limitations. Operators now can quickly and easily create inspection programs and manage daily runtime operations with very little intervention. As a result, both high-mix and high-volume manufacturing lines can recognize immediate yield-improvement automated inspection results. In addition to real-time process feedback, many proponents of automated inspection have praised the substantial time reduction on first-article inspection and line changeovers. By using the latest network and communications methods, there are unlimited possibilities in how data is recorded and retrieved.

In-line or off-line review stations can seamlessly convert the inspection results into an efficient rework process by identifying the defective areas of the PC board assembly and recording the actions performed by the operator. The operator's actions and machine data then can be analyzed via Web-based SPC and statistical quality control software packages to create an instant snapshot of the process via standard Internet browsers on a desktop PC. Finally, AOI and AXI have been following the trend of most recent technologies to provide more performance for less cost. The resulting price/performance ratio of these systems has become a driving factor in the ever-increasing acceptance of these technologies. Whether high-volume or high-mix, both large and small companies can quickly realize the value in automated optical and X-ray inspection. When considering the power of AOI and X-ray systems that can be used in multiple process locations with unlimited data collection and reporting capabilities, the benefits are compelling.

Contact: YESTech, 2762 Loker Avenue West, Carlsbad, CA 92010
☎ 760-918-8471 fax: 760-918-8472
Web: www.yestechinc.com ❏

See at APEX Booth #445.