X-Ray Inspection System

By Don Miller

Today's high-density chip packages—including ball grid arrays (BGAs), microBGA, and flip chips—have opened a vast array of possibilities for PCB designers. But along with the opportunities come some tough inspection tasks that must be done quickly and efficiently to bring competitive product to market.

Faced with this dilemma, many manufacturers are taking a closer look at X-ray inspection. This technology is proving to be an effective and cost-efficient tool to discover shorts, opens, voids, and misalignments of the solder balls on boards manufactured with these new package types.

Current Test and Inspection Systems

Manufacturing defect analyzers (MDAs), in-circuit testers, and vision inspection systems have been the primary tools used to verify the manufacturing process. While MDAs and in-circuit testers verify correct electrical paths, they cannot determine voiding, bad solder adherence, or cold solder joints.

Vision systems can find visible defects on PCBs. However, these systems only check surface errors, not the hidden solder joints of today's BGA, flip chip, or J-leaded devices.

X-Ray Systems

X-ray inspection, already an effective tool for inspecting semiconductor packages and other test applications, verifies the integrity of hidden solder joints on surface-mount devices. As shown in Figure 1, these systems quickly find the hidden process errors that vision systems, MDAs, and in-circuit testers cannot detect.

For years, semiconductor manufacturers have routinely used X-ray inspection to detect and measure die-attach voiding, bond-wire integrity, and package integrity (Figure 2). Newer, ultra-high-resolution X-ray systems even offer solutions to detect and analyze failures down to micron levels.

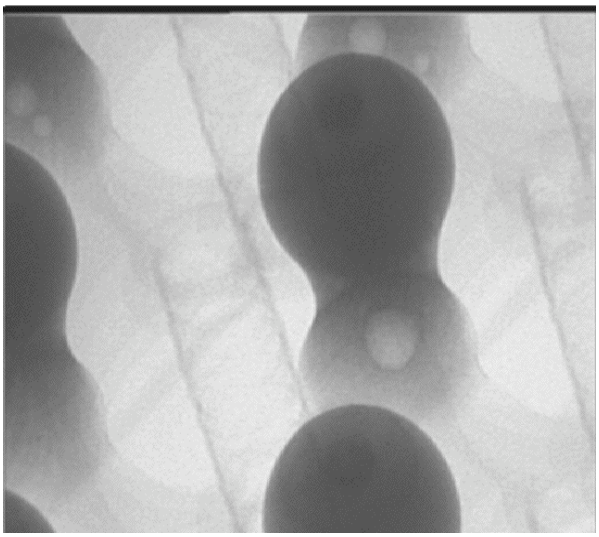

Figure 1: Lifted BGA solder balls

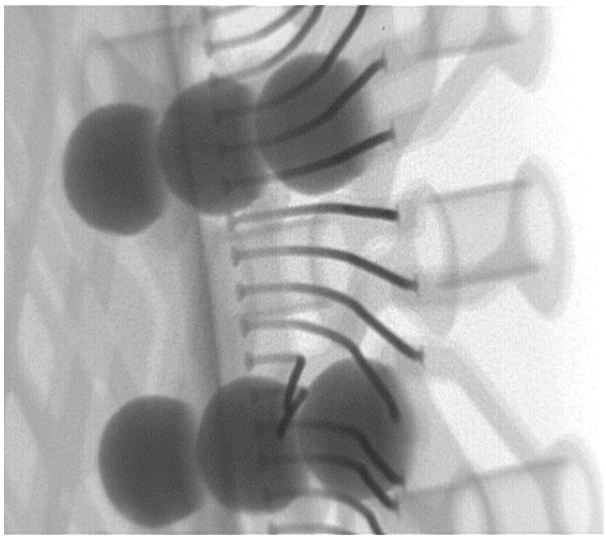

Figure2: X-ray with high resolution and magnification inspecting IC bond wires

Improving Quality at Production

X-ray inspection can be used at many steps in the manufacturing process, including incoming inspection of components, process monitoring, and failure analysis. Now, X-ray systems inspect PCBs built with BGA and other surface-mount devices after reflow to verify the manufacturing process.

Initially, manufacturers may require 100% inspection to ensure accurate component placement, alignment, and solder-joint integrity. But as the manufacturing process is refined and perfected, X-ray inspection primarily is used to monitor production quality.

For applications where product liability dictates and absolute reliability is required, X-ray systems are used to ensure quality. Satellite, implanted medical device, and military electronics manufacturers routinely X-ray 100% of their products.

Choosing the right X-ray System

Choosing the proper X-ray system to meet your needs can be a challenging task given the choices in capabilities and price ranges for systems available today. Before you make a purchase, consider all the requirements to be placed on the system and the value of the cost savings to be derived by implementing it into the manufacturing process. Table 1 details the X-ray sources required to accurately detect many process faults and other defects at various production stages.

As more and more designers incorporate BGAs and other area array package types in their designs, X-ray inspection systems are becoming a vital inspection tool. These systems check for bridging between solder balls or shorts, misregistrations, missing balls, and voids such as partial balls or holes in the solder (Figure 3).

Justifying these systems is easy because most production failures can be attributed to these process errors. Without X-ray inspection, these errors may only be discovered at functional or final test—or worse, with failures in the field.

Important selection factors include the initial cost, resolution and magnification, image processing features, reliability, and degree of automation desired. Systems can range from basic manual units starting at $50,000 to fully automated, in-line systems costing more than $500,000.

X-ray systems do not require costly fixturing. Also, the latest systems are easy to use and install quickly, leading to fast payback cycles.

Application	Minimum Resolution
Gross Defect	50 microns
General PCB inspection and quality control: BGA; die attach	10 microns
Bond wire; fine-pitch lead and solder joint, microBGA; Flip chips; PCB failure analysis and process control	5 microns
Bond wire cracks; delamination; microcircuit failure and process development	1 micron

Table1: Recommended x-ray system resolution for process applications

Manual, Semiautomated, or Fully Automated?

Manual systems generally provide the most flexible and economical solution for X-ray inspection and typically are implemented where 100% inspection is not required. Usually, these systems are used in various stages in the manufacturing process including incoming inspection of components, process monitoring, quality control, and failure analysis.

With manual systems, an operator visually analyzes an X-ray image and determines what represents a defect. As with any operator decision, results will vary with operator skill, time of day, throughput requirements, and other factors. However, these systems still offer the greatest inspection flexibility and the quickest implementation time without in-depth operator training or system programming.

Semiautomated X-ray systems provide a higher level of inspection sophistication by using machine vision and programmable device-positioning tables. These systems inspect device placement and solder integrity based on preset gray-level parameters.

Inspection sites typically are programmed by "teaching" locations with simpler boards or using CAD placement information and navigation programs for more complex boards. Although an operator still is required for subjective decisions, the machine vision-based X-ray inspection is inherently more reliable and offers greater throughputs than possible with manual inspection.

Fully automated X-ray systems are most commonly used in high-volume/low-mix manufacturing applications or other instances where product-liability issues dictate 100% solder-joint inspection. These systems feature pass-through conveyors and operate at line speeds.

Inspections are fully automatic and based on a rules-based approach to image analysis. As a result of the required programming demands and performance criteria for this type of X-ray system, the inspections tend to be application specific.

The fully automated systems generally offer statistical process control information as an option. Some automated systems also perform cross-sectional or 3-D inspection of solder joints on double-sided boards. These systems require significant amounts of programming and operational support and usually are best suited for high-volume/low-mix applications.

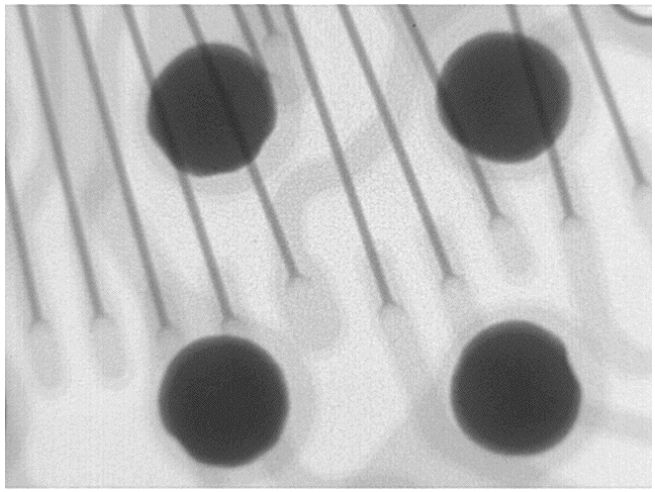

Figure 3: Automated x-ray inspection of a mounted BGA identifies shorted and undersized balls

Conclusion

To meet the demands placed on devices and PCB manufacturers by new technologies and increased competition, X-ray inspection systems help set up and control the manufacturing process, analyze prototypes, and identify process faults. With the variety of systems available today, X-ray is a cost-effective way to fill the void in today's inspection requirements.

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In 2007, the company open SEMICON ASIA PTE LTD to cater its Singapore customers and to support its growing list of customers, and plans to expand in Vietnam and China for the future market.

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