SMT

AXI Conquers Hidden Joint Defects

Lamniographic automated X-ray inspection (AXI) allows for solder-joint inspection, including those hidden under area array packages. AXI also can find most solder defects during production, making it suitable for analyzing joints on an area array package.

By Jeremy Jessen

The use of components with hidden joints is rising as system designers attempt to meet demands for increased speed and package miniaturization. These area array package types come in many varieties including Collapsible or Plastic Ball Grid Arrays (PBGAs), Non-Collapsible or Ceramic Ball Grid Arrays (CBGAs) and Column Grid Arrays (CGAs). Common board layouts have gone from using one custom IC in a high pin-count BGA of fewer than 250 pins on each board, to multiple array area package types.

The use of these types of area array packaging leads to several categories of defects that must be detected in production. Defects that most commonly occur with area array packages are opens, missing, solder bridges, misalignments, insufficient solder and voiding. Current methods of high-speed and automated optical inspection are limited when inspecting area array packages for defects. These techniques allow for inspection of the first several rows of a component along the visible edge of the package. The majority of the joints are hidden under the package and inaccessible to visual inspection. In-circuit test (ICT) can verify the electrical functionality of a BGA and determine the presence of a defect, but test-point access can be limited, meaning that opens on redundant power and ground connection cannot be found.

Lamniographic automated X-ray inspection (AXI) allows for solder-joint inspection, including those hidden under area array packages. This technique also finds most solder defects in the production environment, making it a complete defect inspection method for analyzing joints on an area array package and identifying solder-joint defects.

Area Array Solder Joint Inspection

The lamniographic AXI system uses several basic image-processing techniques to identify an area array solder-joint defect. To analyze a joint, a profile of the solder joint is created along both the *x*- and *y*-axes. This profile determines the edges of the joint. Once these are identified, a region of interest is created on and around the joint. This region is used to measure the diameter of the joint, as well as the thickness of the joint based on its grayscale value. The measurements then are used in a series of basic algorithms to determine whether the joint has an open, insufficient solder or solder-bridge defect.

An insufficient amount of solder paste, lack of solder paste on the pad, poor wetting or poor solder-joint formation during reflow can cause an open on a BGA or CGA pin. Open solder-joint connections are determined by diameter measurements. For CGA solder joints, the diameter of the pin-to-board solder joint is compared to its nearest neighbors. A CGA joint will be smaller than its nearest neighbors because of either a lack of solder on the pad, or all the solder wicking up the column. This technique is used to identify either a completely open solder joint or an insufficient solder joint.

For BGA solder joints, the diameter of the pin at the mid-ball level is measured for opens, while the diameter and thick-

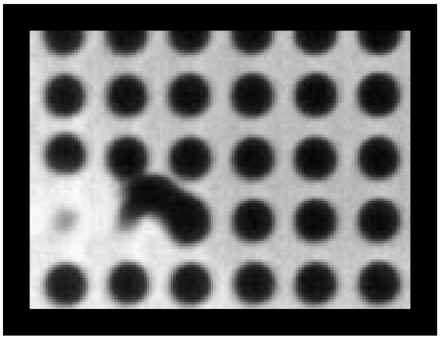

Figure 1. Solder bridges

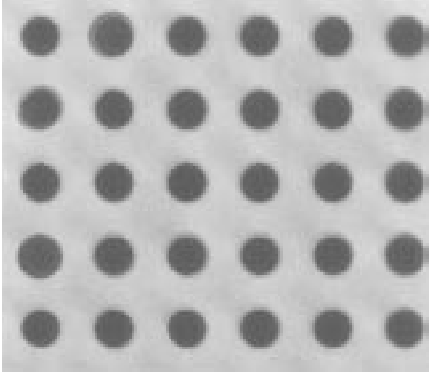

Figure 2. Improper joint formation

ness of the pin is analyzed for insufficient solder. The diameter will be larger at the mid-ball than its closest neighbors when the joint is open due to improper joint formation (Figure 2). The diameter and thickness measured off of the pin will determine insufficient solder.

Solder bridges form when solder wicks across one or more pins (Figure 1). AXI identifies this defect in BGA pins by measuring the grayscale surrounding the joint. However, with CGAs, the more solder used on the pins creates a shading effect for X-ray imaging. The shading reduces the brightness of an X-ray image, resulting in possible false solder-bridge defect indictments. Solder bridges can be inspected, but because of excessive shading in some component types, solder-bridge inspection must be disabled.

This process of analyzing solder joints has proven successful in catching opens, solder bridges and insufficient solder defects on BGA and CGA joints. The impact of these defects ranges from failures at functional testing, preventing board shipment-to-product field failures for end customers. To ensure on-time quality product shipment, these defects must be caught and repaired during production.

BGA and CGA Joint Inspection

To demonstrate the effectiveness of lamniographic AXI on area array packages, the results from a contract manufacturer using an automated X-ray inspection unit* to inspect multiple types of BGA and CGA packages are examined.

The first board type inspected was Board A. Board A was populated with 22,277 solder joints — 13,859 of which are part of either a BGA or CGA package. The BGA pins were setup to be inspected for solder bridges, opens and insufficient solder. The CGA pins were setup to be inspected only for opens due to excessive shading.

The manufacturer produced and inspected 1,155 Type A boards within an eight-day time frame. During this period, AXI indicted 1,978 BGA pins and 195 CGA pins, which were validated by the manufacturer as true solder defects. The CGA pin defects identified were all opens that needed to be removed and replaced. Much of the opens of the CGA were due to pin damage prior to placement and insufficient solder paste (Figure 3). All of these defects had occurred near the center of the CGA package.

The BGA showed 1,978 valid defect indictments. Of those, 1,713 were pins with an insufficient solder amount. Insufficient solder is a defect that allows a board to pass in-circuit and functional tests, but reduces board life and causes field failures. Insufficient solder joints are addressed during production, removing the potential of a solder defect to cause a field failure. During board production, a lower occurrence of solder bridges (263) and opens (2) were identified and validated. Through AXI, the area array packages for board Type A had a defect per million opportunities (DPMO) rate of 355 in real solder defects (Table 1).

Board Type B was populated with 23,000 solder joints — 13,859 of which were part of a BGA or CGA package. The BGA pins were inspected for solder bridges, opens and insufficient solder. The CGA pins were inspected for opens and solder bridges. The manufacturer produced and inspected 2,427 Type B Boards within the same eight-day time frame. During this time, AXI identified 330 valid BGA defects. The majority of the defect calls (183 pins) were identified as having insufficient solder. Forty-one pins were identified as having opens and 106 solder bridges were identified, requiring repair during the eight days.

During this inspection, the solder-bridge test was activated for the CGAs. A total of 330 bridges were detected with 465 pins found to be open. All CGA defects were valid and repaired during production. Table 2 shows AXI DPMO results BGA and CGA pins on Board Type B.

For Boards A and B, AXI made false

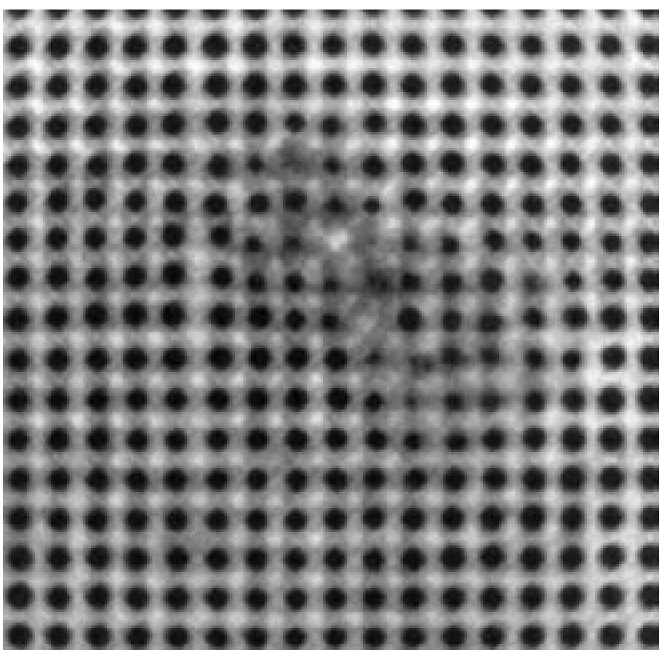

Figure 3. Opens due to damage prior to placement and insufficient solder paste.

TABLE 1

Real DPMO for 1,155 Boards Inspected

	Board A – BGA Defects	Board B – CGA Defects
Real DPMO Insufficient	291	n/a
Real DPMO Solder Bridge	45	n/a
Real DPMO Open	0.3	19.28
Real DPMO Total	336.3	19.28

TABLE 2

Real DPMO for 2,427 Boards Inspected

	Board A – BGA Defects	Board B – CGA Defects
Real DPMO Insufficient	31	n/a
Real DPMO Solder Bridge	18	56
Real DPMO Open	7	79
Real DPMO Total	56	135

TABLE 3

False DPMO for Boards A and B

	BGA False DPMO	CGA False DPMO
Board A	219	94.84
Board B	96	0

defect indictments. False indictments can occur for several reasons — a slight change in the process may require adjustments to the AXI test application. Large components also can cause heavy shading, making accurate measurements difficult. In both cases, AXI test applications will need occasional maintenance. Board A had a much higher false-DPMO rate for BGA and CGA components. When the Board B test application was developed, program maintenance was completed prior to the eight-day testing period. With increased program maintenance the false-DPMO rate was reduced for the area array packages on Board B compared to Board A. In the case of CGAs on Board B, all defect indictments went through the repair team, resulting in actual defects requiring repair. This resulted in a 0 false DPMO for Board B (Table 3).

Conclusion

Area array packages have become standard components on most PCBs. Many high-complexity PCBs have at least 60% of the total number of solder joints in area array packages. This results in at least 60% of solder-related defects that cannot be inspected using optical systems. Unknown solder-related defects might be identified by in-circuit test or functional test, but there is a risk for defect escapes or component damage during repair. This can result in either delayed shipments or product failure. Lamniographic AXI offers a suitable inspection method for these joints, as well as the entire PCB. SMT

* Agilent 5DX Automated Inspection Unit

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