

# X-ray Choices for SMT Manufacturing:

## SUMMARY

In an X-ray inspection system purchase, as part of a test-functionality strategy within SMT manufacturing processes, different types of equipment are available from a range of manufacturers. In many cases, there is a complementary choice of automated 3D X-ray and off-axis 2D X-ray inspection.

**BY Tami Pippert, AGILENT TECHNOLOGIES and David Bernard, Ph.D., DAGE PRECISION INDUSTRIES**

X-ray systems are automated inspection tools capable of detecting defects within complex assemblies at line speeds and with a structured image-review process. Manual or off-axis 2D X-ray inspection systems, on the other hand, are off-line failure-analysis tools providing detailed defect analysis with high-resolution imaging and oblique-angle viewing capability. While there are choices between these methods, in most manufacturing environments, the need for both sets of functionality exists.

### 2D and 3D X-ray Systems

In-line or automated 3D X-ray inspection systems, commonly referred to as AXI, are inspection systems that quickly and automatically inspect PCB assemblies (PCBAs). While 3D AXI is used to provide 100% defect coverage, of particular interest is its ability to non-destructively inspect components with optically hidden solder joints, such as BGA and quad flat pack no lead (QFN) devices. The speed of automated 3D X-ray systems allows uncompromised test coverage of an entire PCBA at the rate of the production line. Automated 3D X-ray inspection systems offer fast and repeatable inspection capability without compromising defect coverage to increase throughput.

One advantage of AXI systems is that they provide process and defect information for

all inspected joints on PCBAs. 3D AXI generates separate X-ray images of the top and bottom-side of a given PCBA, allowing independent analysis by automated image-processing software. Because these systems are flexible in terms of implementation and ease of programming, they can be adapted to changing manufacturing needs, whether for in-line or off-line operation.

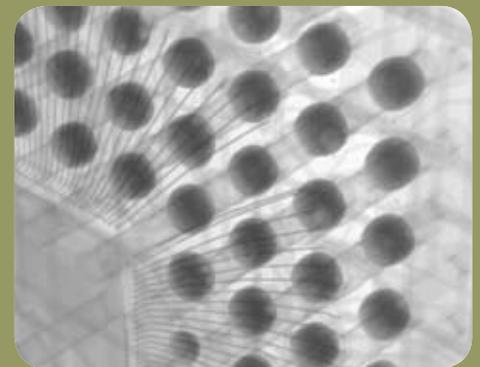
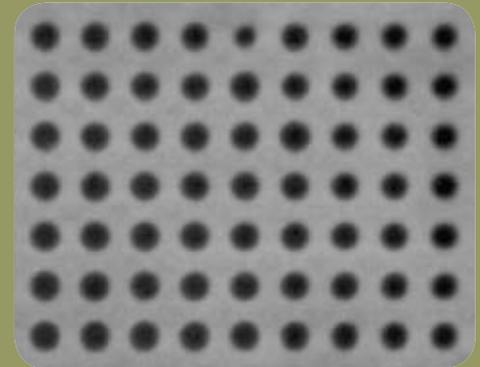
Manual or off-axis 2D X-ray inspection

Both automated 3D X-ray inspection and off-axis 2D X-ray provide a useful set of strengths that can be applied within the SMT production process. Communication between the two systems bridges any gap between these methodologies.

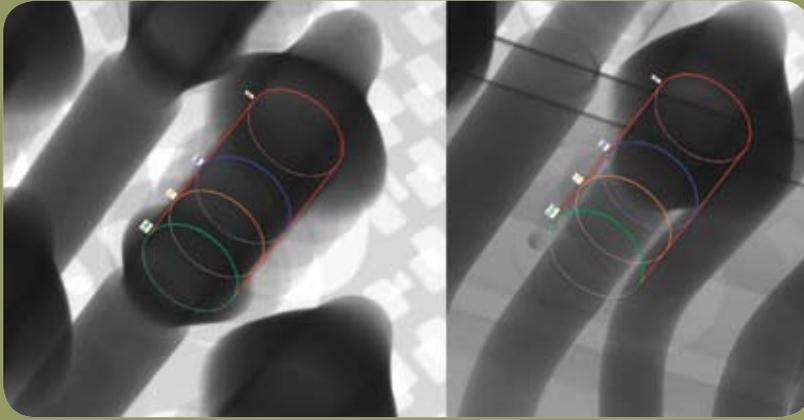
### Integrated Test and Inspection

Board-level assemblers need and use test-and-inspection for two key reasons — defect coverage and process control. The primary function of automated optical inspection (AOI) and automated X-ray inspection (AXI) systems is to provide overlapping and complementary coverage during manufacture, which is then combined with in-circuit test (ICT). While some defects will indeed be identified by several of these test techniques, in many integrated AOI/AXI/ICT case studies, when using these complementary and overlapping methodologies, any coverage gaps are minimized.<sup>1</sup> This is known to increase overall product quality assurance relative to ICT and functional test processes.

As the name implies, automated 3D



**Figure 1A & B.** Automated 3D and off-axis 2D X-ray images of insufficient BGA solder joints.



**Figure 2.** Off-axis 2D X-ray images of thru-hole solder joints with inspection overlays showing good and unacceptable fill levels (see modified image).

## Bridging the Gap

Increased use of fine-pitch area-array packages continues to drive the need for X-ray inspection, since this technique can inspect, verify, and aid the repair of hidden solder joints, as well as confirm rework quality. Having complementary X-ray inspection techniques available that enable fast in-line defect detection with off-line confirmation and diminished repair difficulty will continue to grow in importance as device evolution continually challenges assembly processes.

Integrated repair and quality tools are available that provide actionable information directly from an automated 3D X-ray system to an off-line, high-resolution, off-axis 2D system for direct analysis and confirmation of the most complicated hidden joint defects.<sup>4</sup> Direct communication between these systems bridges the gap between the different inspection technologies and provides critical information to be passed along to repair stations and process experts, facilitating effective repair and process improvement (Figure 3).

This market-driven communication capability between 2D and 3D types of X-ray systems results in a toolset that provides a non-destructive way to verify non-visible defects, and allows users to quickly identify suspect solder joints without time-consuming manual search and movement of an off-line analysis system.

Intra-system communication tools indicate the results of the automated 3D system test, together with CAD files, to the

systems generally perform non-destructive defect analysis and process control. The basic premise of off-axis 2D X-ray inspection is its ability to detect hidden defects and function as a feedback tool for refining assembly processes. Systems typically are situated for off-line batch inspection, making them flexible for auditing ongoing production and failure analysis. A single system is able to support failure analysis for a number of manufacturing lines.

Off-axis 2D X-ray inspection systems have improved image quality with high magnification and resolution, which provides detailed feature recognition within inspection images. The most significant advantage of these off-axis 2D systems is their oblique-angle viewing ability that allows them to perform inspection and measurement of hidden solder interconnections typically associated with complex area-array packages. With this oblique-angle viewing capability, off-axis 2D systems have the ability to see interconnections that would otherwise be obscured by other components mounted on double-sided PCBAs. For example, any solder ball variations that could indicate opens under a single PBGA device will be more obvious when viewed at an oblique angle.

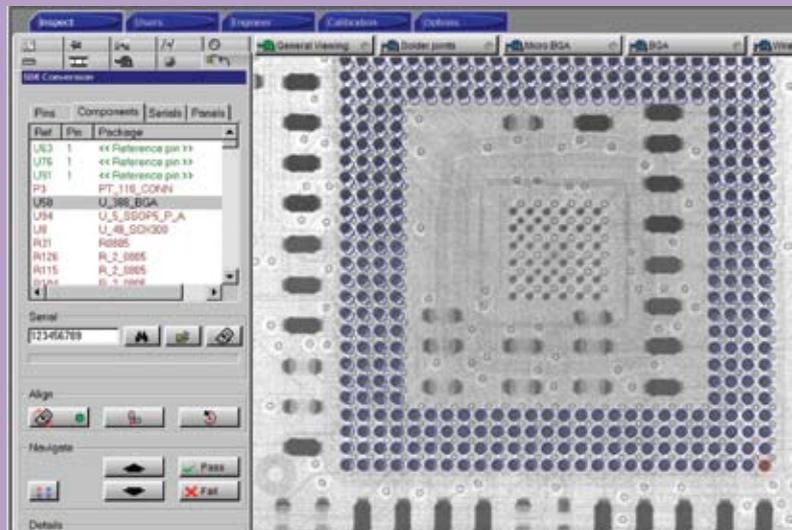
## Complementary Inspection Strategy

There is an application and need for both types of X-ray inspection tools, so it is fitting to see how they interact in a typical production environment. AXI systems excel at providing 100% inspection of double-sided PCBAs and locating problems or manufacturing defects quickly in production, while off-axis 2D X-ray systems analyze and confirm the problem off-line.

Modern board-level assemblers face the challenge of detecting, analyzing, and re-

pairing defects associated with hidden joints of BGAs, column grid arrays (CGAs), QFNs, and paste-in-hole (PIH) thru-hole components.<sup>2</sup> Automated 3D X-ray systems inspect both sides of the board to identify potential defects, while off-axis 2D X-ray confirms a defect prior to rework and repair. An example of this complementary test and inspection strategy is the detection and analysis of insufficient BGA solder joints (Figure 1).

Another example of 3D AXI and off-axis 2D X-ray systems complementing each other is in detecting incomplete PIH solder joints. Once a potential defect is identified by the 3D system, the off-axis 2D system is used to measure the fill percentage of thru-hole joints, with partially filled joints highlighted against an inspection scale (Figure 2).<sup>3</sup>



**Figure 3.** Direct interface between automated 3D and off-axis 2D X-ray systems.

off-axis 2D system automatically, and provide alignment points, board orientation, and naming conventions. This unmanned transfer of critical information allows automatic full point-and-click access by the off-axis 2D system operator to areas needing further review. The end result is an increase in the speed and accuracy of the manual inspection process, the provision of an enhanced quality regime, and the ability to achieve all of this with production-line personnel rather than diverting process engineering resources.

### Conclusion

In the final analysis, the choice between an automated 3D X-ray inspection system and an off-axis 2D X-ray system depends on the

requirements of the specific overall test-and-inspection strategy into which it will be incorporated. Selecting the optimal X-ray inspection methodology for a given application is, therefore, a function of the role with which it will be tasked. A critical issue that should be considered is synergistic strengths that both X-ray inspection methodologies possess and the benefits that can be derived from implementing both technologies in unison by means of a direct communication protocol.

SMT

### REFERENCES:

<sup>1</sup> Scheiber, Steve, "Study Compares Effectiveness of Test & Inspection," Test & Measurement World, August 2007.

<sup>2</sup> Balsavar, Rajiv, "X-ray Inspection of Voids in

BGA Joints with Respect to the IPC-7095A Specification," APEX 2006.

<sup>3</sup> Bernard, David and Willis, Bob, "Measurement Variation in the Fill of Intrusively Reflowed Lead-free Solder Joints with Different Board Finishes by X-ray Inspection," SMTA International 2005.

<sup>4</sup> Agilent 5DX User Group, March 1-2, 2005.

---

**Tami Pippert**, automated X-ray inspection product manager, Agilent Technologies, may be contacted at tami\_pippert@agilent.com. **David Bernard, Ph.D.**, product manager X-ray systems, Dage Precision Industries, may be contacted at d.bernard@dage-group.com.

[www.agilent.com](http://www.agilent.com)

Product specifications and descriptions in this document subject to change without notice

©Agilent Technologies 2008  
Printed in USA, June 27, 2008  
5989-8934EN