Modern 2D X-ray Tackles BGA Defects

In recent years, a greater number of BGA devices are being mounted on both sides of PCB assemblies (PCBAs) to facilitate product functionality, compounding density and complexity. Because of this, effective test-and-inspection methods are needed to identify common BGA defects such as opens, shorts, cracks, head-in-pillow, and voiding. Significant enhancements to the capabilities and performance of modern 2D X-ray systems have accumulated during the last several years with new X-ray sources, detectors, and ergonomic features designed to improve the efficiency and productivity of the inspection process. These new developments have expanded the role that 2D X-ray inspection plays in providing a non-destructive method of identifying BGA defects in a production line. Modern 2D X-ray is helping improve process yields at the EMS facility.

Developments in 2D X-ray

X-ray sources and digital detector technology have significantly improved, to the point where submicron feature recognition as fine as 950 or 250 nm is achievable. This allows inspection of finer detail and a corresponding increase in the detection of potential defects. Sealed transmissive, filament-free X-ray tube technology was developed for maintenance-free or minimal-maintenance operation, which reduces downtime in an active production environment.

Development in imaging systems also has advanced; systems can provide real-time digital inspection at 1.3 or 2.0 megapixels with 65,000 grayscale levels viewed on up to 24" ultra-high-definition LCD monitors. These offer 6,000 or even 9,200x magnification. Meanwhile, the superior image quality and enhanced feature recognition brought about by these advancements in modern 2D X-ray systems is making the inspection process faster, more effective, and higher reliability.

Common BGA Defects

BGA defects may occur when BGA devices are reflowed. These types include micro-cracks, head-in-pillow, and voids. Tilt-angle capability, or oblique-angle viewing, is critical for identifying BGA defects such as head-in-pillow, micro-cracks, and small voids. It is good to use tilt or oblique angles of 55 to 70° and rotate the X-ray detector at 0 to 360° around the examined joint. This is not trivial to execute, but can be easily accomplished using modern 2D X-ray equipment.

Head-in-pillow: The phenomenon commonly referred to as head-in-pillow occurs when incomplete wetting of the entire solder joint results in the solder paste coalescing around a BGA solder ball after reflow. Head-in-pillow defects are difficult to detect with automatic X-ray inspection (AXI) or lower-performance 2D X-ray systems. They may require destructive cross sectioning to identify and confirm this deficiency when the assemblies fail at in-circuit test (ICT) and functional test (FT). However, head-in-pillow defects can be identified easily with off-axis X-ray inspection using modern 2D X-ray systems, without destroying the PCBA. Separations of less than 1 mil (0.001") can be detected with 2D X-ray and confirmed with scanning electron microscope (SEM) imaging (Figure 1).

Micro-cracks. BGA micro-cracks below 1 mil are challenging for all X-ray inspection systems to detect. The proper use of tilt and rotation angles and the right X-ray parameters — kilo volts (kV) and power — prove to be crucially important in detecting cracks that are only several microns in size. Larger cracks of 3 mils (0.003") and above easily are detectable with modern 2D X-ray systems by selecting proper tilt angle and X-ray parameters. An example of this is a 6-mil (0.006") crack imaged with a modern 2D X-ray system; presence of the crack was confirmed with SEM imaging (Figure 2). A micro-crack of approximately 1 mil in size also is obvious at the BGA chip side.

As previously stated, detecting micro-cracks of 1 mil or smaller remains a challenge. However, these can be identified using modern 2D X-ray systems (Figure 3). The tilt and rotation angles need to be adjusted carefully, since the two angles are among the key factors playing a critical role in identifying small micro-cracks.

Voiding. Virtually all X-ray inspection systems have the capability to detect voids within BGA solder balls. However, repeatability of the void percentage measurements of current AXI machines remains an area of potential improvement. Modern 2D

Figure 1. Head-in-pillow defects imaged with 2D X-ray and SEM. The separation is approximately 5 µm.
X-ray systems are used to verify the void calculation results provided by AXI systems and also to fine-tune the AXI program. Sometimes, a customer will ask for AXI voids-measurement data for all BGA solder balls. It is a benefit to use 2D X-ray to verify AXI algorithm settings. Typically, 2D X-ray inspection is more accurate in identifying voids and determining void size. Modern 2D X-ray machines also are able to perform automatic inspection of BGA devices for voiding percentage, ball diameter, and shape. Keep in mind, however, that the 2D X-ray inspection time takes longer than AXI.

Modern 2D X-ray is a transmission technique, and it does not provide several slices to locate BGA voids. Instead, using oblique viewing to tilt and rotate the imaging device, modern 2D X-ray has the capability of precisely identifying void location within the ball. This can be confirmed with SEM images of a void for an identical joint location.

Conclusion
Modern 2D X-ray systems have capabilities similar to that of an X-ray microscope and are a powerful tool for improving process yields. With tilt-angle viewing that facilitates the inspection of double-sided boards, these systems have proven effective in finding common BGA defects including micro-cracks, head-in-pillow, and voiding.

Capabilities and performance of modern 2D X-ray systems come from new X-ray sources, detectors, and ergonomic features designed to improve the efficiency and productivity of the inspection process. The factory floor is continually looking for X-ray inspection techniques that have the advantages of both AXI and modern 2D X-ray systems: improved speed, accuracy, and greater operator independence.

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