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Special Edition: Because electronic parts packaging is frequently discussed on Domestic and International NEPAG telecons, we bring you this article by JPL's Phil Zulueta.

Inspection of Area Array Package Interconnections

Today densely packaged electronic assemblies often use area array packages like ball grid array, ceramic column grid array, flip chip, etc.

However, the use of area array packages in these advanced designs is generally not suitable for companies that ensure their quality through inspection and repair processes.

The nature of area array package construction hides solder connections from optical view, making the practice of post-assembly visual inspection practically impossible. To maximize the benefits of area array packaging, robust process controls must be applied during assembly design and fabrication.

Many manufacturers find implementing highly focused process controls difficult. To maximize yields and maintain a high degree of quality, industry standards such as IPC-7095, "Design and Assembly Process Implementation for BGAs" help standardize area array-related PCB designs and PWA assembly workmanship characteristics.

As a result of using such standards and implementing robust process controls, industry reports post-solder defect levels of 0.5 ppm and less.

This questions the need for post-reflow solder joint inspections of area array components resulting in a varying degree of inspection practices, ranging from 0 to 100 % of final assemblies.

It is well-known that voids in area array interconnections, either in the ball or column, or at the interfaces between these and the package or board, reduce the thermal fatigue life thus compromising part reliability.

No degree of visual optical inspection or electrical testing will detect these voids.

For process control, quality assurance and especially for electronics in safety critical applications or space applications, inspection of these interconnections is absolutely vital.



Endoscope image of CGA Interconnects (Courtesy Advanced Packaging)

Visual Inspection

Visual inspection of area array package interconnects is limited to the outer rows. This inspection, based on external shape and appearance of the external rows, provides a quick and uncomplicated assessment.

However, visual inspection of the outer rows only serves as an indicator of some solder interconnect problems, e.g., planarity, package alignment to the PCB pads, lifted pads, opens, debris and insufficient or un-reflowed solder.

This inspection can be accomplished with either an optical endoscope (a fiber-optic tube) or a rotating prism system attached to a viewing device.



Rotating Prism image of BGA interconnects (Courtesy Hirox)

Two-Dimensional (2D) X-ray

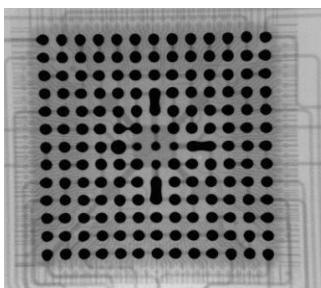
Although it is possible to detect solder joint defects by visual inspection, transmissive radiation (X-ray) techniques could possibly inspect all area array interconnects beyond the outer rows.

Using X-ray inspection and cross-sectional techniques to inspect and characterize solder interconnections of area array package assemblies is vital for realizing fabrication process control parameters.

Structural verification methods like automated paste inspection, automated optical inspection and automated X-ray inspection, complemented with traditional electrical verification methods, are essential elements of an effective structural inspection and test strategy for highly complex products.

2D X-ray, providing a top-down image of the board or package area being viewed, or more advanced systems offering the ability to examine samples for defects at oblique angles, can distinguish a variety of solder defects such as voids, shorts, excess solder or insufficient solder reflow.

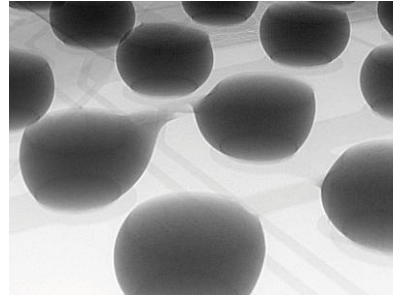
But for some applications, 2D imaging is insufficient due to the assembly's density and complexity. This is one of 2D X-ray's primary limitations, especially when imaging double-sided boards.



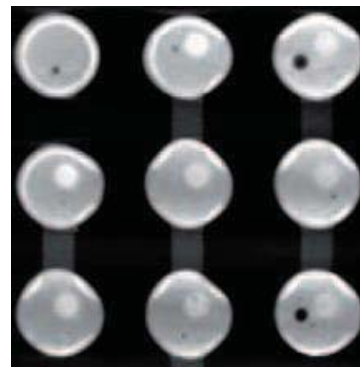
2D X-ray of a BGA on a PCB shows solder bridges, excess solder and insufficient solder reflow defects. (Courtesy FeinFocus)

Since X-rays penetrate devices on both sides of the board, the devices on one side can be partially obscured by devices on the other side.

In this case, oblique angle imaging can reduce this problem, depending on the complexity of the assembly inspected. Overall, 2D X-ray inspection of area array interconnects is a quick, economical inspection method, but also has its limitations.



Oblique 2D X-ray view of BGA (Courtesy Xylon)



Solder voids (Courtesy Xylon)

Other Inspection Methods

There are a variety of other inspection techniques that are new or are being proposed to inspect area array interconnections, but may not be in general or widespread use.

Many of these techniques supply indicators of the quality of the soldered joint but do not provide sufficient information to qualify the soldered condition of all area array interconnects. This short article does not address all of these methods.

Solder joint cracks or crack initiation is one of the critical defects of area array interconnects that cause high resistance or intermittent connection and eventually open under repeated thermal excursions. This type of defect does not always show up in X-ray images.

However, recent improvements in three-dimensional (3D) X-ray imaging show promise in identifying these types of defects.

3D X-ray Imaging

Standard 2D X-ray offers image resolution of 8 to 10 μ m, while many advanced 3D systems can achieve a resolution of less than 1 μ m.

Another notable advantage of 3D X-ray inspection is that the process can result in a complete picture of the area of concern.

For example, solder balls on the underside of BGAs can be viewed from all sides, and defects such as insufficiently wetted or cracked balls can be easily identified.

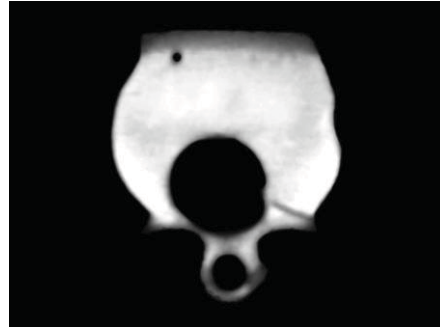
Micro-focus computed tomography (μ CT), also called 3D laminography, enables the detection, assessment and localization of typical defects, such as size and location of voids, shorts caused by excess material, opens due to insufficient material, micro-cracks and solder deformations: all of which are typical causes of reliability problems or failure.

In addition, where imaging and data reduction processes previously took hours, newer technology systems reduce scanning and image reconstruction time to be less than 2 minutes.

This reduction in imaging time comes at a high financial cost, but may still be justified by the increase in confidence of interconnect reliability.



3D view of BGA balls with voiding close to pad and small fractures (Courtesy Xylon)



3D slice of single BGA ball with μ -via showing micro-crack and various voids (Courtesy Xylon)



3D view of single BGA ball with μ -via (Courtesy Xylon)

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