AXI systems as an integral component in electronics manufacturing

Figure 1: X-ray systems offer a glimpse into hidden depths

Goethe once said, 'We only see what we know.' When it comes to quality assurance for electronic assemblies, the opposite is true – we only know what we see. The proportion of solder joints that are hidden on complex assemblies is already well over 30 percent, and this figure is expected to rise in the future. Yet anyone who relies solely on AOI will have a visual test coverage of just 70 per cent in certain circumstances. Electronics manufacturers, particularly in the area of high-quality assemblies, cannot afford this gap in an era of global competitive pressure.

Manual (MXI) and automatic X-ray inspection (AXI)

AOI systems have become an integral part of any modern SMT production line. They are used as pre- and post-reflow inspection systems to ensure the quality of the finished assembly. Until now, however, X-ray systems have been used much less than AOI equipment. Recent years have seen a massive increase in the sales of X-ray systems, however. Manual X-ray systems, so-called MXIs, are largely used to inspect hidden solder joints at random. They offer a relatively affordable introduction to the world

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of X-ray technology and are often used for series production launches and for analysing prototypes. MXI systems are able to generate high-resolution X-ray images with a high level of detail. Similar to a microscope, an assembly is inserted into the system by hand and the ‘ideal X-ray image’ can be generated by way of the free movement of the X-ray imaging chain and the unit under test. The disadvantages of this manual systems are of course the manual loading and evaluation. One-hundred-percent inspection of all manufactured assemblies is usually not possible due to cycle times. What’s more, evaluation of the images is not consistently identical due to the human factor. The same image may be interpreted very differently depending on the operator's experience and knowledge. In addition, automatic logging and archiving of results and measured values is usually not possible. This where automatic X-ray systems, so-called AXI, have the advantage. With a slightly lower resolution and a lower level of detail in the X-ray images, AXI systems enable fully automated loading, inspection, evaluation and results reporting of the assemblies. Similar to an AOI system, the AXI system uses a pre-parameterised test program to inspect the solder joints with image-processing algorithms.

2D, 2.5D and 3D X-ray technology

In practice, three technologies are used for X-ray imaging. Orthogonal projection is known as 2D X-ray imaging. If the circuit board is irradiated at an oblique angle, this is known as 2.5D X-ray imaging, or oblique projection. In addition to 2D and 2.5D X-ray, there are also various method of 3D X-ray analysis. 3D technology enables the display of digital micrographs. Horizontal and vertical sections through the assembly and its solder joints are therefore possible, for example. 3D X-ray images are always synthetically generated images and are computed from multiple oblique 2.5D images. In AXI systems with digital flat-panel detectors, 8-16 of these oblique shots are usually used for 3D image rendering in in-line operation. As a result, 3D AXI systems are always slower than conventional 2D/2.5D equipment, which only work with a single shot. In the case of assemblies populated on both sides, however, 3D imaging is the only reliable way to obtain a high visual test coverage. This technology enables the solder joints on the upper component side to be separated from the solder joints on the lower component side and tested and evaluated independently of each other.

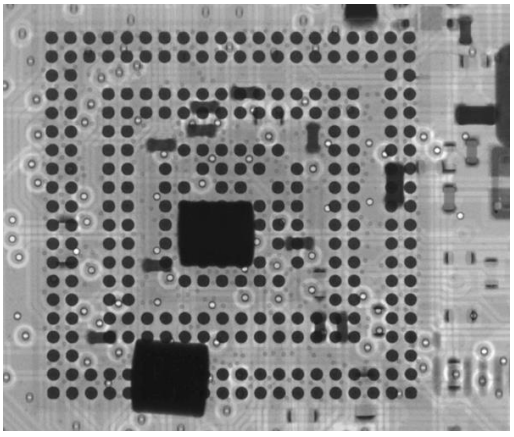

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Figure 2: 2D X-ray image with superposition of the two component sides

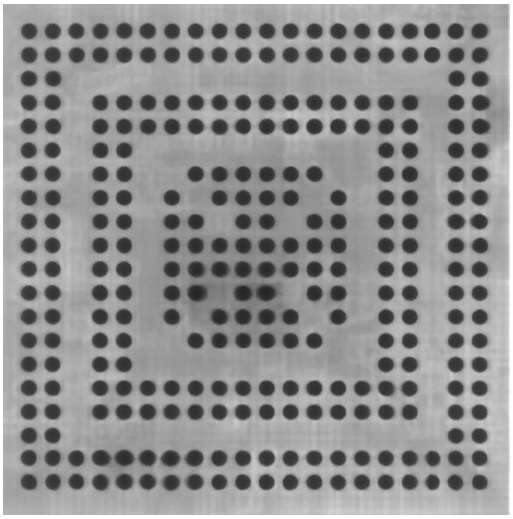

Figure 3: 3D slice of the BGA (upper component side)

Stop-and-go vs. scan

To prevent the 3D AXI system from becoming a bottleneck in the SMT line, X-ray imaging must be quick. Conventional flat-panel detector systems have a clear disadvantage here: In order to be able to capture the individual 2.5D images for the 3D image rendering, in most cases the flat-panel detector and the circuit board are moved on a circular path. For example, if eight 2.5D images are required for 3D image rendering, an image is taken every 45° on the circular path. Yet every movement and every image captured cost time. If you compare the best technology currently available when it comes to AXI systems, the 3D image acquisition times using flat-panel detectors are around 3-5 seconds per 3D field of view. This does not sound critical at first, yet the 3D image acquisition time is multiplied accordingly by the number of fields of view (FOVs) that are required for testing. If the assembly to be tested is also configured as a multiplier, the image acquisition time increases rapidly.

The size of the field of view is crucial

Currently, 6-megapixel CMOS flat-panel detectors offer a good price-performance ratio. They have a pixel count of 2,900 x 2,300 pixels, for example. With a pixel resolution of 10µm/pixel, a field of view of just 29mm x 23mm is obtained with this rather large detector. This is smaller than the area of a standard postage stamp. Often, 3D AXI systems with flat-panel detectors are therefore too slow and are unsuitable for regular use. This is also illustrated by the following example: The assembly contains 20 sub-circuits and is populated on both sides. For each sub-circuit, a BGA with a pitch of 0.5 mm and three QFNs with a pitch of 0.4 mm must be tested. A resolution of 10µm/pixel is used. Around two 3D X-ray image fields are needed per sub-circuit. Assuming about 4 seconds per 3D FOV, the image acquisition time is calculated as follows: 20 sub-circuits * 2 3D FOVs per sub-circuit x 4 seconds = 160

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seconds. This is purely the image acquisition time. Then there is the time for the PCB handling, the image rendering and evaluation time and the time for transmitting measurements and result values.

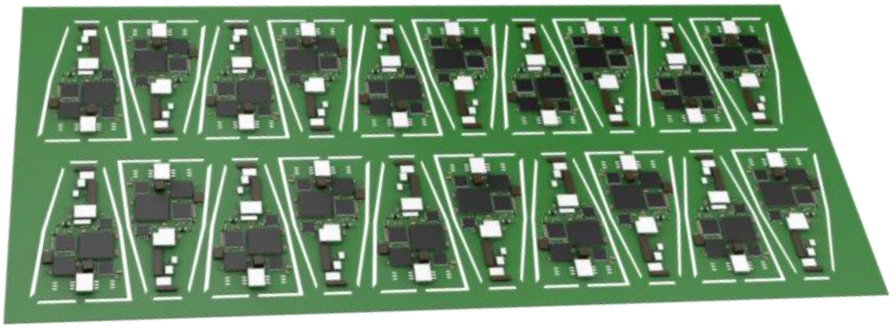

Figure 4: Assembly panel with assemblies populated on both sides; image acquisition time with conventional flat-panel detectors: approx. 160 seconds

To reduce the image acquisition time, GÖPEL electronic has developed the MultiAngle Detector 3 for the X Line · 3D AXI system. This detector enables scanning image acquisition and captures 3D images on the move. It makes time-consuming stop-and-go movements a thing of the past. At the heart of the all-digital detector are multiple scan lines, which allow simultaneous X-ray imaging from different directions. Typically, 18 oblique projections are generally used for one standard 3D image. This figure is typically just 8-16 in conventional flat-panel systems. In addition, the field of view is significantly wider than in conventional flat-panel detectors. At a resolution of 10µm it is approximately 45 mm, making it significantly wider than in comparable 6-megapixel flat-panel detectors. Extremely short cycle times can therefore be achieved with the MultiAngle Detector 3. The X Line · 3D is therefore ready for regular use and the 100% X-ray inspection associated with it. One positive side effect of the rapid image acquisition is a significant reduction in exposure of the assemblies to radiation. The shorter the irradiation time, the lower the radiation dose.

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Figure 5: Programming software PILOT AXI for creating AXI test programs

From the everyday world of X-ray

The main task of the X Line · 3D is to detect soldering defects in concealed and visible solder joints. Open, lean, fat and unsoldered solder joints are every bit as much a part of everyday inspection life as air pockets, stray balls of solder and short circuits. The system has multiple test functions for automatically detecting the faults. Similar to an AOI system, a test program is created and parameterised based on CAD data. Only the images for evaluation of the solder joints are X-ray images. The X Line · 3D uses a holistic 3D concept. In other words, all image data is greyscale-calibrated and geometrically calibrated. The typical perspective view known from 2D and 2.5D images is not used. Standardised X-ray slice images are always used. This hugely simplifies the creation of test programs and enables the use of a uniform component library.

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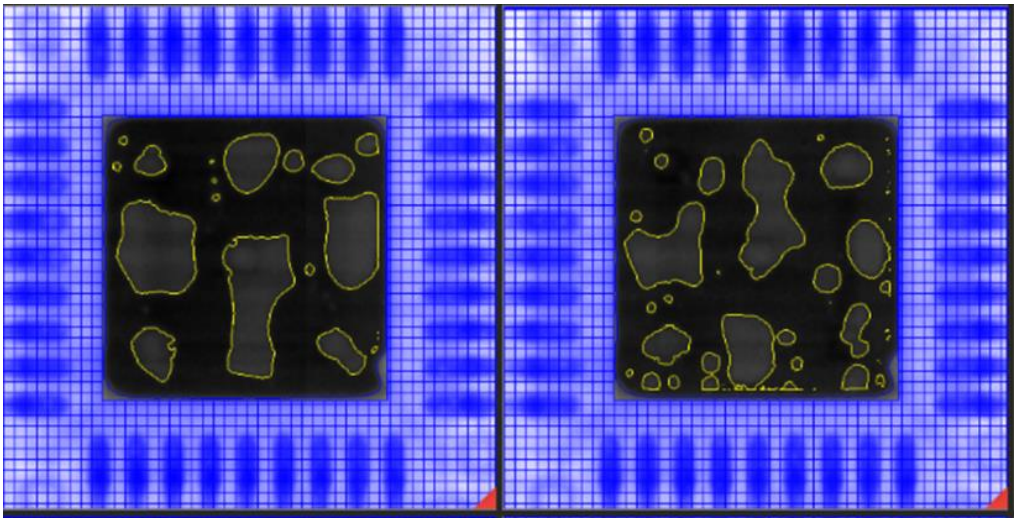

Figure 6: Fully automated void detection in heatsinks of a QFN

Smart factory with added value

Test results and measurement values, such as solder surface or void content as percentages, are stored in a central database and can be used for classification of the fault by humans and also for optimising the entire process. At the heart of the central data storage is the PILOT Connect software from GÖPEL electronic. The results data from SPI, AOI and AXI are all combined here and can be displayed together on the PILOT Verify verification station. Not only can GÖPEL's own inspection systems be connected but also equipment from third-party manufacturers. Assessment of the automatically detected abnormality is much easier due to the fact that the faults are displayed together.

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Figure 7: Monitoring and controlling the X-ray system in a smart factory from a tablet

Summary

AXI systems allow a 100-percent inspection of concealed and visible solder joints. Automatic loading, inspection and results logging allow complete traceability of test results. The human factor is largely eliminated by the automatic test program, and test results are therefore comparable. Thanks to fast, scanning 3D X-ray imaging, the X Line is · 3D does not become a bottleneck in the production line. In addition to easy programming and operation of the system, it can be embedded seamlessly in the world of the smart factory.
Although the initial outlay for an X-ray system is higher than for AOI systems, they are indispensable for 100% visual test coverage and it is no longer possible to imagine modern production lines without them.

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