As electronic components become smaller and even more complex, quality requirements are growing more and more stringent. For most industries like electronics, automotive or aerospace, zero defects are a necessity. The reliability of electronic assemblies strongly depends on solder joint quality. Acceptability criteria are mainly based on joint shape and dimensions. In order to ensure highest quality standards, it is necessary to offer new and automated testing methods. High-resolution X-ray technology may provide the only feasible means to inspect such components.

Given the modern trend towards miniaturisation and complexity, inspection systems are being pushed to the limit. Especially in harsh environments, or those such as automotive which have high safety requirements, these inspection systems are more important now than ever before.

By using latest microfocus and nanofocus x-ray technology and advanced inspection software, most common solder joints may be inspected automatically – providing higher quality information than looking on the PCB surface or only at one of its slices. With the right software and technology, fully automated inspection guarantees deeper analysis with highest repeatability in an effective, timesaving manner. Once it has been established that X-ray technology is necessary, the only question that remains is whether the throughput of the SMT production line is suited for highest defect coverage by using inline inspection or if an offline µAXI system is the best choice.

**High-resolution X-ray inspection**

The basis for maximum defect coverage is a high-resolution X-ray inspection system. Whether microfocus or nanofocus, X-rays penetrate a specimen using a cone-shaped beam that generates a magnified x-ray shadow image on the detector. The achievable resolution or image sharpness principally is influenced by the focal-spot size of the x-ray tube, which varies from a few microns for a microfocus tube to less than 1 micron for the latest nanofocus tubes (Figure 2). New nanofocus tubes achieve a detail detectability down to 200 nanometers (0.2 microns). They use different modes to get an optimised mix of x-ray intensity and resolution. The image magnification, a key feature for analysis, is determined by the beam’s geometry. Advanced X-ray systems provide magnifications well above 24000x without software zoom.

For the inspection of BGA and other solder joints, oblique views are essential. If oblique views are achieved by tilting the sample, the magnification decreases due to a longer focus-object distance. To avoid this, the ovhm technique provides oblique views at up to 70 degrees without loss of magnification plus rotation by 0-360 degrees, while the isocentric ovhm control keeps the field of view locked (Figure 3).

**Automated X-ray inspection**

Most of the solder joint properties and defects can be detected
automatically. However different solder sizes and inspection objectives require different automation processes. There are three types of automation:

**Semi-automated visual inspection**

With very small lots, full automation is often not worthwhile because of the substantial programming and optimisation time needed. But even if during visual evaluation of the x-ray images repetitive actions are desirable, partial automation appears nevertheless useful. For this the printed circuit board positions and the associated x-ray parameters are pre-programmed into the inspection program, so that the operator always has comparable inspection views. Individual quantitative measurements, for instance the determination of voiding percentages, may be integrated as automatic steps.

**Fully automated inline inspection**

When a 100%-inspection is required, integration of the automatic x-ray system into the production line seems to be unavoidable. But this sets the line cycle time as an upper limit for the inspection time and, hence would probably limit the depth of inspection. In contrast to automatic optical inspection (AOI), the generation of a high-resolution x-ray image needs significantly more time. This can partly be balanced by higher tube power, which, however, increases the focal spot size and deteriorates the image quality. In other words, for a package which should be inspected with a certain test depth (defect coverage) as well as with an acceptable pseudo-defect and escape rate, a certain inspection time is necessary which might exceed the cycle time. For example, the 300 solder joints of a PBGA can be thoroughly examined within a cycle time of 20 seconds, while an examination of 3000 solder joints in the same time would possibly be checked merely superficially and with significantly higher escape rates.

**Fully automated offline inspection**

With smaller numbers of assemblies with high variety or with restriction on large spot checks, the fully automatic inspection in batch mode turns out to be a useful alternative (Figure 4). The boards are loaded into the x-ray system either by the operator or an automatic board magazine unit. Offline, repetitive actions are desirable, partial automation appears nevertheless useful. For this the printed circuit board positions and the associated x-ray parameters are pre-programmed into the inspection program, so that the operator always has comparable inspection views. Individual quantitative measurements, for instance the determination of voiding percentages, may be integrated as automatic steps.

Inline or offline x-ray inspection?

To ensure the product quality hitting current and future zero-defect requirements, only the inspection strategy for a minimised pseudo-defect and escape rate should determine the inspection time. With common inline AXI, the inspection depth is determined by the cycle time of the line. But AXI takes much more time than AOI, and the speed of SMT lines as well as use of packages with hidden solder joints and quality standards are increasing continuously. To ensure highest defect coverage offline AXI gives time for the highest resolution inspection. Despite this dilemma, there are some tools which can mitigate the slower inspection times in AXI systems.

**µAXI with highest defect coverage**

To achieve maximum defect coverage in automatic solder joint inspection, the new µAXI platform from phoenix|x-ray is using micrometer resolution and highest magnification of details. phoenix|x-ray provides calibrated high precision offline AXI systems including the x|act software package for fast and easy CAD based fully automated inspection of solder joints. Small field of views with micrometer resolution, 360° rotation and oblique viewing up to 70° enable operators to meet the highest quality standards. x|act is a specifically designed, intuitive inspection program, which requires only a simple, one-time configuration. The component’s CAD-data is read into the x-ray system and laid over the image (live CAD-overlay). This allows the user to have the complete sample data available at all times, even when using oblique views (tilt and rotation).
Efficient CAD programming and minimised setup time

To minimise programming time, x|act uses CAD import. Filters can be used to extract the required information from customised data formats. The standard data format used with x|act is the neutral data format (ndf) which contains information about the position and size of component pads.

For ease of use, the software works with pad-based information (Figure 5). The operator can link specific inspection strategies to each type of pad. Different pad types usually require different strategies. If a strategy needs to be changed in an existing program, it can easily be done by marking all pads of the same type and generating a new link to the new inspection strategy. After importing the data, the software automatically generates the inspection views. The programs can be generated offline and are portable to all inspection systems of the same type, saving time and money.

3D auto-referencing and optimised positioning accuracy

x|act software runs on standard phoenix|x-ray microfocus systems using calibrated high-precision CNC manipulation. The system uses a unique local 3D height and distortion referencing method (Figure 6). Highest precision is achieved by measuring as many fiducials as required. By using x-rays instead of optical triangulation sensors, the method does not depend on the quality and reflectivity of board surfaces. The image chain is calibrated and any distortion is automatically compensated. The combination of all these efforts allows for maximised positioning accuracy even at oblique viewing (70°) and rotation (360°).

Live 3D-CAD overlay and highest magnification in oblique view

The software provides a live overlay of the x-ray image and the CAD information. This overlay is available even for oblique views (Figure 1). The pad ID is visible at any time. In addition, the pad-specific inspection results are accessible by mouse click. Even if the system is used for manual inspection only, the CAD overlay is very beneficial, because it allows easy pad identification. The overlay technique is extremely convenient for the operator due to perfect orientation at any time (reliable identification of a specific joint or a specific group of joints on a board with thousands of solder joints can be time consuming).

Fully µAXI-capable inspection system

Combining high-quality automated x-ray inspection, 2D x-ray inspection, and 3D computed tomography in one single system, the microme|x offers high value from both a technological and economical standpoint. The microme|x is a high-resolution automated x-ray inspection system that is most suitable for failure analysis in the semiconductor and electronics industry. It comes standard with an ultra high-performance 180kV/20W x-ray tube for sub-micron feature recognition of less than 1µ, a high-resolution 2Mpixel digital image chain, and a high-contrast 24” flat display. The microme|x is particularly suited for the inspection of high-contrast features and, due to its unique 180kV/20W x-ray tube, high-absorbing objects.

Unlike traditional tubes of 160 kV, the development of the 180kV/20W high-power tube with its new generator technology from phoenix|x-ray makes inspecting highly radiation-absorbent samples such as electronic assemblies, with or without heat sinks, a far simpler affair.