2-D or 3-D Inspection: Do You Have to Choose?

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Flexibility in x-ray inspection combines 2-D real-time imaging with 3-D axial computed tomography.

The role played by x-ray systems in the inspection of today's electronic assemblies is well understood. Unlike machine vision and optical inspection equipment, x-ray systems penetrate materials to expose hidden solder joints on area array devices. Once a need for x-ray inspection equipment has been determined, the next question is: Which is best for the application—two-dimensional (2-D) or three-dimensional (3-D) imaging?

2-D vs. 3-D Imaging

For most applications, 2-D x-ray systems serve the need, providing a top-down image of the board or package being viewed. More advanced systems also offer the ability to inspect for defects by rotating the part being inspected at oblique angles to the x-ray beam. The target area—the component or interconnect being checked for a defect—can thus be viewed from multiple orientations.

Two-dimensional (2-D) systems consist of: a) an x-ray source (sealed or open tube), b) a fixture for holding and manipulating the part being inspected (sample) and c) the radiation detector. While x-ray tubes are available in various configurations and performance capabilities, open microfocus tubes are used primarily for the high-resolution requirements of electronics assembly and packaging. Such tubes can provide a spatial resolution in the range of 1 µm, with geometrical magnifications up to 2400x.

An open tube is a stainless steel tube in which a vacuum is continuously created, while a sealed tube is generally a tube in which the vacuum is created at the time of manufacture. Sealed tubes may not offer as sharp an image as open tubes. They are also less suitable for high magnification applications because of the larger minimum distance required from the focal spot to the object and usually have a shorter life due to consumption of the electron gun (filament).

The *manipulator* is a device for x-y-z positioning and rotating/tilting of the sample with precision. The manipulator should be capable of directional and rotational speeds that can be varied for requirements ranging from quick overview searches at low magnification to very low speeds at high magnification.

The *detector* processes the information of the x-ray image in real-time into an image of visible light that can be observed and assessed by the human eye. While the most common detector is a combination of video camera and image intensifier that converts the x-rays into visible light, other types of detectors recently developed include high-dynamic cameras and flat panel direct digital detectors (DDDs).

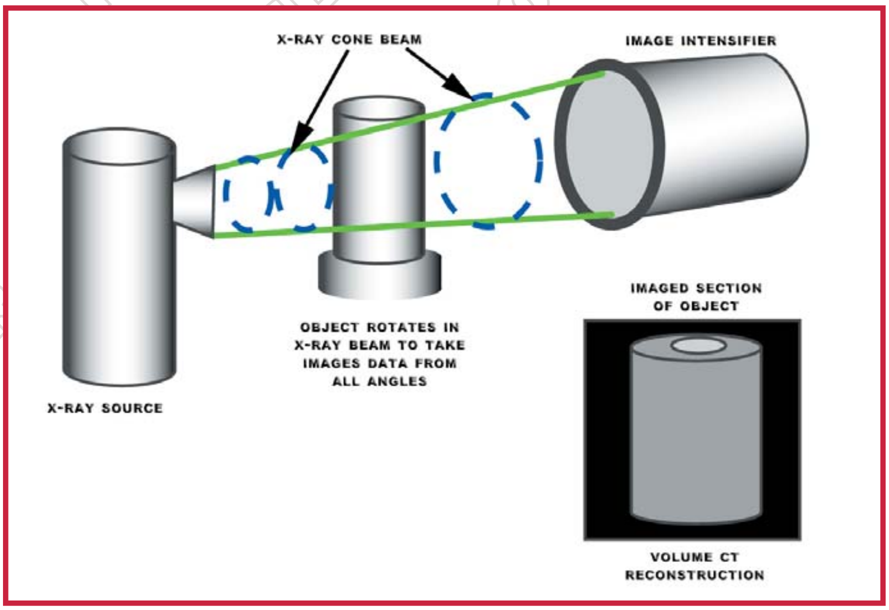

FIGURE 1: Cone-beam method of computed tomography (CT).

The primary advantage of 2-D x-ray inspection is the savings in time in viewing an image, as 3-D analysis can take twice as long, or even longer. The primary limitations of 2-D systems become apparent when imaging double-sided boards. Since x-rays penetrate through components on both sides of the board, the devices on one side can be partially obscured by devices on the other side. Oblique angle imaging can lessen, and even eliminate, the problem, depending on the x-ray system and the complexity of the assembly being inspected.

The most notable advantage of 3-D x-ray inspection is that it results in a complete picture of the area of concern. Solder balls, for instance, on the underside of ball grid arrays (BGAs) can be viewed from all sides, and defects, such as insufficiently wetted or cracked balls, can be easily identified.

So, do you need 2-D or 3-D imaging? The requirement may not always be known until the middle of the inspection procedure, or the requirement may change. An x-ray system that offers both capabilities may be the ideal solution for the majority of applications.

Combining 2-D and 3-D

An ideal system that combines 2-D and 3-D imaging would incorporate a choice of: a) a standard open microfocus tube or b) a multifocus tube, which enables the operator to select either a microfocus, nanofocus or high-power mode, depending on the requirements of the application. The system would perform high-resolution 2-D inspection for optimum processing speed, while enabling the operator to switch to 3-D for inspection of parts and interconnects that cannot be adequately viewed using 2-D.

Inspecting with 3-D

Three-dimensional capability can be achieved with a process called *axial computed tomography* (ACT) with volume rendering software. ACT is a reconstruction technology. By taking multiple 2-D views and by calculating the volume data (voxels), a 3-D image is constructed. Typically, for 3-D inspection, the region of interest (ROI) of the part or interconnect is first located. Then, a multitude of images is taken in a 360º circle by rotating the sample and the x-ray beam being projected in a cone, as can be seen in Figure 1. Using software, the images are subsequently recombined into a 3-D visualization model.

The manipulator for the 2-D/3-D x-ray system would enable movement around six axes, the movement being either programmed by computer numeric control (CNC) or controlled with a joystick. The multiple axes, thus, would provide flexibility in positioning the sample for optimum imaging. The high accuracy of the axis allows precise point-to-point measurements in 2-D mode. In 3-D mode, wall thickness or void volume measurements can be performed directly from the 3-D model due to the known size of the voxel data.

The combined 2-D/3-D system should let the operator shift from one mode to the other easily. Thus, if a BGA, for instance, is being viewed using the 2-D mode, and a 3-D image is required to examine for a possible defect, the operator could punch a certain tactile key on the keyboard and begin the 3-D operation. As the multiple images are taken in the 360º circle around the part and the 3-D image is constructed by software, the operator could begin to view the image on a second screen. Once viewing is completed, the operator could then shift back to 2-D and continue the process.

True-X-Ray Intensity

The accuracy of a 2-D/3-D x-ray system can be attributed to a unique control technology called *true x-ray intensity* (TXI). Unlike systems that measure and control the input level of the high voltage and current to the x-ray tube, TXI is a process that controls and stabilizes output intensity for x-ray emission even over a long time range of inspection (hours). The result is a sharp, consistent 2-D image and data that can be reconstructed into a complete 3-D image. Without precise control over the x-ray intensity, the reconstructed 3-D image would be degraded

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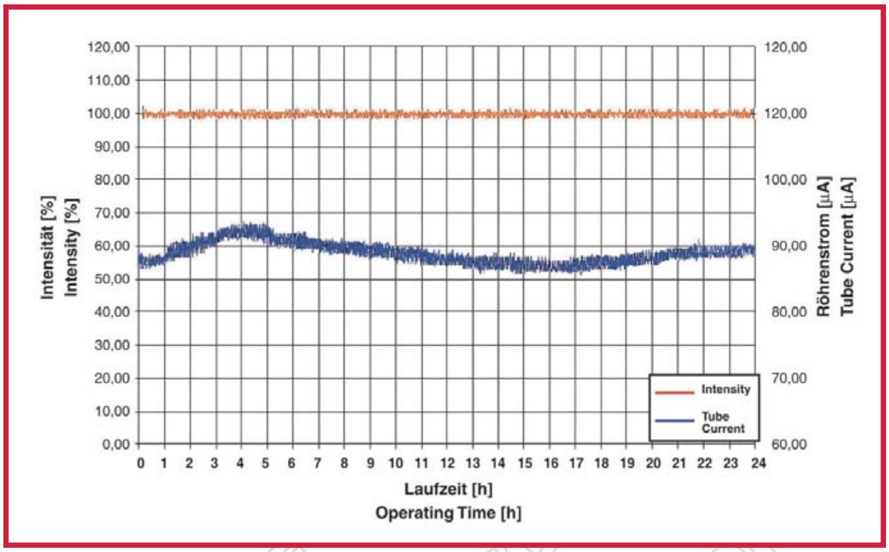

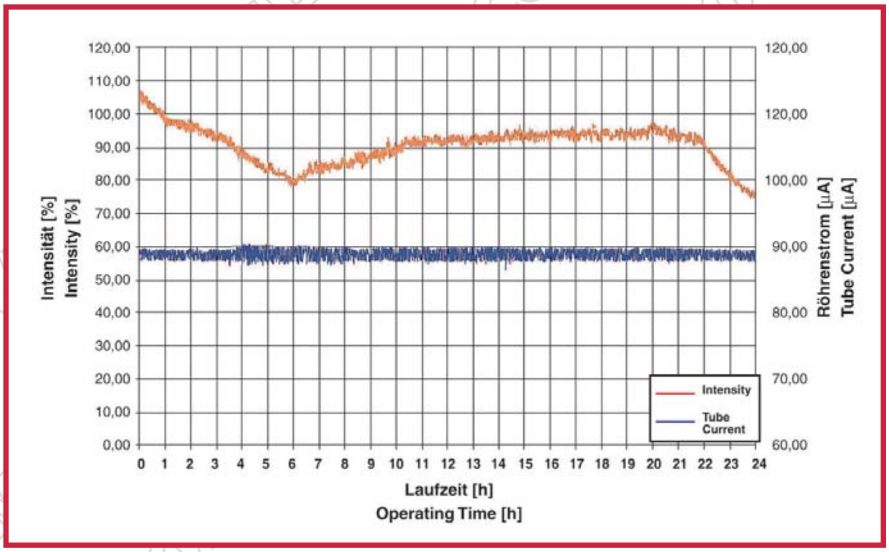

FIGURE 2: X-ray output intensity is shown in red, with TXI (top) and without TXI (bottom).

and may not even be possible to achieve (Figure 2).

Applications for 2-D/3-D Inspection

Combined 2-D/3-D x-ray inspection is, first and foremost, a design, production and quality control tool. For R&D requirements, a 2-D/3-D x-ray inspection system can be employed to develop and refine the manufacturing process, and it is ideal for inspecting prototypes during pre-production. It can also be used for reverse engineering of existing products.

In terms of electronic assemblies, a 2-D/3-D system could be used off-line to inspect components and packages. Cracks, voids, delamination and other component anomalies can be observed and measured in either the 2-D or 3-D mode, whichever most accurately depicts the defect. This type of system is also particularly useful in the manufacture of sensors and relays and other micro-electromechanical (MEMS) and micro-opto-electromechanical (MOEMS) devices. ■

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