Workflows for Assessing Electronic Devices
Using 3D X-Ray Microscopy and Nanoscale Tomography

ZEISS CT and X-ray Microscopy Solutions
Make the Invisible Visible
Meet Failure Analysis Demands with Non-Destructive Testing Technologies

Increasingly complex electronic packaging architectures have created new manufacturing challenges and higher risks of failure. Since the physical location of failures are often buried within these complex 3D structures, conventional methods for failure analysis (FA) are becoming less effective. Advanced non-destructive testing (NDT) technologies are required to meet these FA demands.

The Use of 3D X-ray Imaging

One method to increase the confidence of FA assessments is to perform 3D X-ray imaging or computed tomography (CT). An X-ray CT processing algorithm can create a virtual 3D volume reconstruction of the object from multiple radiographic images. These images are collected at different angular positions as the object is rotated by certain angular increments, typically covering 180 or 360 degrees. From the reconstructed volume, internal and external features can be extracted to reveal the object’s 3D structure and morphology.

Where X-ray CT falls short is with resolutions that worsen when the sample size increases. This limitation can be overcome with the use of X-ray microscopes (XRMs). By adding optical magnification, XRMs make possible to preserve (and improve) the system’s spatial resolution as the geometrical magnification decreases. This preservation is possible without major limitations on sample size, as long as the sample physically fits inside the instrument, when resolution-at-a-distance (RaAD) capabilities are introduced in the XRM system’s design.

As interconnect dimensions shrink in advanced packaging architectures, making the thickness and volume of each layer smaller, it is difficult to obtain high-contrast images with conventional absorption/contrast X-ray imaging, especially at nanometer length scales. Fortunately, there are ways to improve the contrast and resolution of XRMs into the nanometer range such as using X-ray focusing elements.
Assess PCB Samples using 3D XRM

XRM Optimizes Electronic Device and PCB Assessment

Due to the non-destructive nature of 3D XRM imaging, the interior arrangements of electronic devices can be imaged without disassembly. This allows observation of the arrangement of internal features of intact electronic components, such as printed circuit boards (PCBs). Structural integrity can be evaluated and checked for the existence of defects or to identify the root cause of failures.

The main workflow for assessing PCB samples using 3D XRM with RaaD capabilities can be summarized in three steps:

1. An operator selects the settings for scanning the sample based on its geometry, size and composition
2. The XRM instrument rotates the sample while the detector collects snapshots or radiographic projections at different angular positions
3. A software reconstruction will use 2D radiographic projection data to generate a 3D volumetric density map of the sample that reveals its internal and external features

The 3D-reconstructed volume can be used for non-destructive inspection using cross-sectional views or 2D slices to see through the inside of the sample — virtually, without physically cutting or destroying it.

While the uneven penetration of X-rays into PCBs can make the quantitative evaluation of small features in PCBs challenging, such limitations are overcome with the use of a high-aspect-ratio tomography (HART) scan modality. HART collects fewer projections along the broad side of a flat sample and more along the thin side. This method optimizes image quality and spatial resolution around the edges of the long sample side.

Types of Defects in PCBs

Aided by the volumetric data generated by 3D XRM with RaaD, several types of defects can be explored in a non-destructive manner during the inspection of PCBs:

- Voids in solder bumps
- Underfills
- Fatigue cracks
- Cold joints known as "head-on-pillow"
- Trace cracks or breaks
- Electromigration
- Broken vias
- Microbump shorts
- Solder bleeds
- Cracks or micro-cracks in silicon wafers
Inspection Challenges with FA Workflows

Correlative FA Workflows for Advanced Electronics Packaging

Small features may be embedded between layers or non-uniformly staggered/distributed along the PCB layer sides. With conventional 2D X-ray inspection or computed laminography, it is difficult to perform defect recognition and failure analysis of these small features. Overcome these inspection challenges with FA workflows that combine 3D XRM (with RaaD capabilities) and nanoscale tomography.

Correlative FA workflows may start with non-destructive approaches for failure confirmation, such as standard 3D X-ray imaging. The next step is to progress to more destructive analyses that require sample preparation for mechanical isolation of a region of interest in an electronic package. To avoid inducing cracks, delaminations, or other artifacts generated by physical cross-sectioning of the sample, nanoscale 3D X-ray imaging can be used after fault insulation for a non-invasive exploration.

After that, further investigation can be performed with the use of nanoprobing or any other advanced FA techniques that may require cross-sectional sample preparation such as:
- Scanning electron microscopy (SEM)
- Transmission electron microscopy (TEM)
- Atomic force microscopy (AFM)
- Energy dispersive spectroscopy (EDS)
- Secondary-ion mass spectrometry (SIMS)

Physical sectioning techniques provide only information from a single cross-sectional plane. The addition of 3D X-ray imaging to FA workflows is essential to accurately determine defect location prior to cutting or opening a device. In some cases, the root cause of a failure can even be identified from 3D XRM data without the need for additional inspection.

Using Deep Learning Techniques for 3D XRM Reconstruction

ZEISS recently introduced the integration of deep learning (DL) based algorithms for CT reconstruction into 3D XRM workflows. Data reconstructions produced by DL-based algorithms can provide up to 4x and 10x throughput improvement at similar or better image quality compared with the results from standard algorithms such as Feldkamp-Davis-Kress (FDK).
Zeiss Opens Up New Possibilities for Failure Analysis

Zeiss Industrial Quality Solutions’ X-ray imaging complemented by additional correlative microscopy investigations provide the most powerful NDT inspection solutions. Manufacturers can gain the ability to increase speed development time and cost efficiency while simplifying FA and quality inspection of semiconductor packaging, printed circuit boards (PCBs) and electronic devices assembled with new emerging technologies.

Zeiss delivers a robust portfolio of NDT imaging and optimized workflows to meet your electronics packaging FA needs.

Nano 3D X-ray Imaging

Zeiss Xradia Ultra 3D XRM focuses a high-brightness X-ray source on a sample by a capillary condenser lens. The purpose of the condenser lens is to provide uniform illumination of the sample throughout the field of view. A Fresnel zone plate objective then forms a magnified image of the sample in the X-ray camera (detector). As the sample is rotated, images are collected at a variety of projection angles which are then reconstructed into a 3D tomographic dataset.

XRM Workflows

Zeiss Xradia 620 Versa can perform 3D XRM imaging workflow for assessing electronic devices. A flat-panel detector is used to scan a full device, such as a smartphone. The zoom lenses of the 3D XRM can then be used on small regions of interest in the device where scanned.

DL-based Techniques

Zeiss DeepRecon is a DL-based algorithm that produces data with enhanced contrast-to-noise-ratio (CNR). DeepRecon preserves fine details and finds clear boundary separations between air and material. This technique reveals voids and cracks that get lost in the noise of traditional CT reconstruction (FDK) data. In addition to improving image quality, the DL-based reconstruction using DeepRecon reduces XRM scan time.
Conclusion

Recent advancements in 3D X-ray imaging allow new FA workflows for electronic devices with the integration of 3D X-ray microscopes and nanoscale tomography. These imaging workflows allow spatial resolution imaging of fine details within electronic devices without interfering with or destroying the root cause of failure.

ZEISS 3D X-ray imaging, correlative imaging workflows and DeepRecon algorithms can contribute to the functional inspection of electronic components. Embrace ZEISS solutions to improve your designs, manufacturing processes and production of versatile electronic devices.

Contact us to learn more information.