

X-ray Computed Tomography for Non-Destructive Failure Analysis in Microelectronics

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Abstract

In this paper a review of the development of x-ray computed tomography (CT) for non-destructive failure analysis in microelectronics is presented. The general operation principle, key design considerations and technical challenges faced by x-ray CT technology are discussed. A comparison between 2D and 3D x-ray imaging capabilities is presented, and critical failure analysis case studies that are hard or not possible to isolate by alternative methods are also discussed, as well as its unique progressive testing capability.

Introduction

The assembly package development roadmap has been increasing interconnect complexity, component density, the number of stacked dice, and material composition, while at the same time reducing critical dimensions. As a result of these trends, the isolation and root cause analysis of defects has become increasingly challenging for traditional analytical tools and techniques. In addition, reduced time-to-information and non-destructive approaches have become critical factors, introducing more challenges into the analytical tools development roadmap. One of these analytical capabilities is 2D x-ray imaging, which is also one of the most extensively used tools in the semiconductor industry to isolate and analyze defects in a non-destructive fashion. Some of these capability challenges are the detection of metal migration and dendrite growth, solder joint non-wetting and cracking at both first and second level interconnect, wirebonds shorting and breakage, etc. One of the x-ray techniques identified as potentially feasible to fulfill these defect detection gaps was x-ray CT [1]. However, the standard assembly imaging techniques of x-ray CT had important limitations in terms of defect detection capability and time-to-data, and thus it needed to be extended into the next generation [2]. Key technical drivers for x-ray CT are the need to non-destructively and quickly detect micron and sub-micron sized defects.

In this paper, we review key technical challenges faced by x-ray CT technology, leading technical developments that have overcome some of these challenges, as well as application development for critical defect detection case studies.

X-ray CT Operation Principle

There are several possible configurations to achieve the challenges of the key drivers; however, all of them relay of a basic operation principle of using an x-ray source to radiate the object at different tilt angles, with a rotating stage providing such angular displacement in equally spaced angles, and a detector collecting the 2D x-ray images at each angle. This is schematically shown in Fig. 1. All 2D images are mathematically superimposed and processed to obtain a three dimensional map of the sample, as it is shown schematically in Fig. 1b. Information is typically displayed as a cross-section, slice view and 3D model.

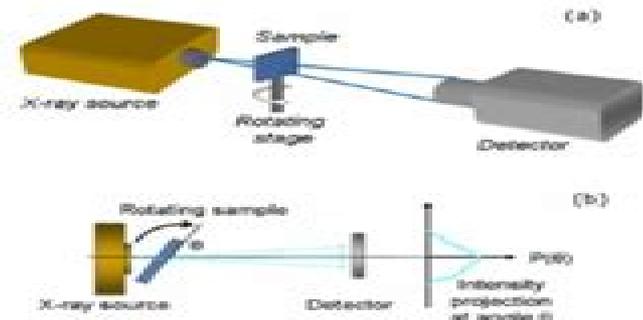


Figure 1: (a) Basic schematic of the x-ray CT setup consisting of x-ray source, rotating stage and detector. (b) The projections at each angle of the intensity of collected 2D x-ray images are superimposed and mathematically processed to generate the three dimensional image.

Key Design Factors in X-Ray CT

In this section we'll review the critical design considerations for X-Ray CT systems that are targeted for failure analysis in microelectronics applications.

Resolution

X-ray image resolution depends on several factors, however, geometric magnification, which is given by the ratio between sample-to-source and sample-to-detector distances, is one of the most critical ones, given by the following expression:

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