

Process Technology/Packaging/Assembly Technology

"Failure Analysis Challenges of Advanced Packaging"

Advanced packaging technologies are reshaping the semiconductor industry by enabling performance, integration density, and system architecture required for artificial intelligence (AI), high-performance computing (HPC), and data center applications. The transition from monolithic system-on-chip (SoC) designs to heterogeneous integration, chiplet-based architectures, 2.5D/3D packaging, high-bandwidth memory (HBM), and co-packaged optics (CPO) introduces new reliability risks and significantly increases the complexity of failure analysis (FA).

This presentation reviews key reliability challenges in advanced packages, including thermal management, solder joint and redistribution layer (RDL) defects, interface delamination, warpage-induced failures, and stress-related damage within heterogeneous structures. As the cost of failure in large AI and HPC devices continues to grow, rapid and accurate root-cause determination becomes increasingly critical.

The presentation highlights recent advances in fault isolation and characterization techniques that improve defect localization in complex package structures, including Electro-Optical Terahertz Pulse Reflectometry (EOTPR), Lock-In Thermography (LIT), Magnetic Field Imaging (MFI), Optical Beam Induced Current (OBIC), and Laser Induced Capacitance Alteration (LICA). Complementary non-destructive imaging methods, such as 3D X-ray microscopy, X-ray nano-tomography, and advanced scanning acoustic microscopy, provide enhanced visibility of buried interconnects and package features.

Key developments in sample preparation are also discussed, including contour milling, integrated laser/FIB workflows, selective dry etching, and advanced mechanical and laser-based techniques that enable efficient defect exposure while preserving failure integrity. Artificial intelligence applications for defect detection, image enhancement, and data interpretation are presented as emerging enablers for increased FA productivity.

Two case studies demonstrate successful root-cause analysis of the failures on advanced packaging devices. Emerging challenges in backside power delivery, hybrid-bonded 3D ICs, silicon photonics, and CPO are also examined, highlighting the need for continued innovation in advanced package failure analysis.

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