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Combining Acoustic Microscopy and X-Ray Microscopy for Metrology Inspection and Failure Analysis in Advanced Packaging

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The rapid evolution of advanced packaging technologies, including hybrid bonding, presents significant challenges for metrology, defect inspection and physical failure analysis (PFA). To address these challenges, innovation in microscopy techniques and related workflows are required. The development of next-generation analytical tools that can tackle technologies for heterogeneous integration of ICs and chiplet architectures is a challenge to engineers at universities, research institutes and equipment manufacturers. With respect to nondestructive imaging, a balance between acquisition speed and achievable resolution is always a consideration for engineers [1]. Scanning acoustic microscopy (SAM) continues to be the tool of choice for inspecting interfacial integrity (e.g. delamination), and detecting defects (e.g. voids, cracks) in bonded wafers [2]. However, conventional SAM techniques reach limits for 3D-stacked dies since highly penetrating low frequency acoustic waves are unable to provide high resolution imaging of high-density submicron interconnects, and because of requirements to spatial resolution of 500 nm and below. In addition, the convolution of signals from various die interfaces makes it difficult to select the correct signal for rendering the right image from the interface of interest. Several beyond state-of-the-art approaches are addressing these challenges. We will demonstrate the detection of voids in through-silicon-vias (TSVs) applying the new GHz-SAM technology [3]. SAM interferometry, where the defocused sound field induces surface-acoustic-waves, provides unique interference patterns associated with the quality of each TSV. Finally, a fully automated high-efficient End-to-End Convolutional Neural Network model classifies thousands of TSVs and provides statistical information [4]. X-ray microscopy and high-resolution X-ray computed tomography (XCT) are well-known FA techniques that have been applied to visualize defects in metal interconnects and package structures such as TSVs, Copper pillars and solder microbumps [5,6]. However, usually a compromise had to be made between image quality and scan throughput, and state-or-the-art laboratory nano-XCT requires a destructive workflow. High-resolution imaging of voids in Cu-TSVs and AgSn microbumps will be shown, using conventional nano-XCT after thinning the Si down to about 50 μm. To image defects with sub-500nm and sub-100nm size, respectively, further development of micro-XCT and nano-XCT techniques are needed. To ensure a highly reliable inspection method, the time for image acquisition must be reduced significantly without sacrificing the resolution of the X-ray images. Ways for a drastic throughput increase are high-brilliance laboratory X-ray sources and the application of AI algorithms for imaging of objects with large form factors (dies, wafers) and high-speed data processing. In addition, we will demonstrate for solid–liquid interdiffusion (SLID) bonded $Cu/Cu_6Sn_5/Cu$ interconnects that in the hard X-ray regime, i.e. at photon energies > 10 keV, destructive sample preparation steps for nano-XCT are not needed [7]. An outlook for a seamless workflow for advanced package FA and defect inspection, that combines acoustic and X-ray techniques to auto-detect and auto-classify defects, with the goal to improve throughput and defect detectability, will be presented.

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