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Scanning Acoustic Microscopy Technologies Applied to 3D Semiconductor Integration Applications

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In semiconductor industry new approaches are employed for increasing functionality and complexity while reducing a systems footprint by integrating components in the third spatial dimension. However, this new design concept requires new and adapted methods for failure analysis and quality assessment. Acoustic microscopy is a powerful method providing detailed information of a samples interior while operating non-destructively. By employing the methods capability of acquiring the information in 3D by performing a rapid acquisition scan full access is given to the samples interior structure and parameters including the elastic properties. However, the new concept of 3D integration required the development of new solutions for providing the full performance of this technique to the developers, manufacturers and failure analysis engineers of 3D integrated technologies.

Recent trends in semiconductor technologies utilize the third spatial dimension for increasing functionality and performance of microelectronic systems and components while continuously reducing a devices footprint. This new concept however, challenges existing and state of the art methods for diagnostics, failure analysis and quality assessment. Therefore the adjustment of existing methods for non-destructive inspection is strongly demanded since, especially in the development phase of a new technology, the non-destructive and total-view assessment of the condition and the localization of defects is of major importance.

Acoustic microscopy is capable of providing 3D information from a samples interior, allowing an exact depth localization of defects and enabling the access to mechanical properties. New semiconductor chip technologies and technologies for 3D integration require exact these information of packaging and interface defects in 3 dimensions. In the current paper novel methodical approaches in acoustic microscopy for non-destructive failure analysis on 3D integrated TSV samples are introduced. The approach combines new concepts in transducer design, customized pulse excitation, high performance digitization hardware systems and intelligent focus solutions for increased accuracy and sample through put. Also the potential of acoustic microscopy hardware operating in the frequency band of up to 2 GHz equipped with specific acoustic lenses allowing for lateral resolutions in the 1 µm range will be demonstrated.

In case of full wafer inspection for high level 3D integration processes, non-destructive inspection commonly faces a high degree of wafer bow. This warpage however, will lead to significant artefacts interfering with features in the bond interface. Due to the high refractive indices encountered in acoustic imaging the spacing between the sample surface and the acoustic lens largely influences the focal position inside the sample. For avoiding these imaging artefacts an intelligent z-axis has been developed that prevents an axial displacement of the focal area allowing for high imaging contrast and resolution with an increased performance in defect localization.

By aiming at ever higher imaging resolutions an increase in acoustic frequency is desired. However, acoustic attenuation exponentially increases with frequency resulting in spectral downshifts and decreased signal intensities. These issues are met by the design of application specific acoustic lenses allowing for a minimum propagation path in the coupling fluid. Acoustic signals received by these transducers contain a large variety of information about the interaction of the acoustic wave on the propagation path [1]. Newly developed signal analysis methods allow for the extraction of these information and also largely contributes to an increased imaging resolution and defect detection. The increased performance of these novel approaches has been evaluated on a variety of flip-chip devices containing regular and micro-bump interconnects as well as TSV's. Acoustic imaging and defect localization will be shown on both the condition of the electrical connections as well as on the integrity of the underfiller required for ensuring mechanical and thermal stability in high performance 3D-integrated devices.

The decreased lateral dimensions of structures contained in 3D- relevant technologies require imaging resolutions in the 1 µm range and detection limits even below that. For meeting those demands a novel high frequency acoustic microscope has been developed operating in the frequency band of up to 2 GHz providing an imaging resolution of approx. 1 µm (@ 1.2 GHz) combined with an excellent sensitivity to surface and near-surface features. Figure 1 contains an electron micrograph in direct comparison with an acoustic GHz-micrograph showing and verifying delaminations non-destructively found approx. 5 µm below the samples surface. The SEM image in the upper part of fig.1 verifies the acoustically found defects demonstrating the high potential of this new acoustic imaging technique.

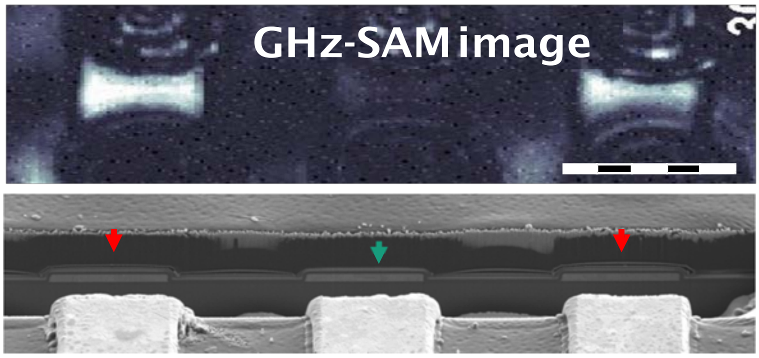

Figure 1. Acoustic GHz-Microscopy employed to an imaging sensor manufactured in 3D-technology. Top: GHz-SAM micrograph of an interconnect structure 5 µm below the surface. Increased intensity can be noted at the outermost routings. The central routing shows a significantly lower signal intensity. Bottom: SEM image of a FIB-prepared cross-section through the acoustically found defects. Delamination of the routings can be noted at the red arrows, while the central routing is well adhering.

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References:

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