Picosecond Laser and Broad Argon Beam Tools for Characterization of Advanced Packages and Devices

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Abstract

A key tool set for semiconductor failure analysis has been and will continue to be electron microscopy. However, “More than Moore,” the emerging solution which relies on 3D stacked chips, to sustain Moore's Law, may challenge failure analysis tools to keep pace.

More than Moore maintains high planar resolution, but with advanced packages and stacked chips, cross-sectional depths increase to perhaps as large as a few millimeters. Until now, mechanical polishing or focused ion beam (FIB) have been the tools of choice for preparing cross-sections for failure analysis. Mechanical preparation may be limited due to the increased fragility of the silicon devices thinned to less than 50 µm within these advanced packages. Gallium FIB’s and even the newer plasma FIB’s may not have sufficient milling speed necessary to expose regions within a large thick package or cross-sectional surfaces of stacked chips.

A precision pulsed laser tool is well suited to this application. It has milling rates orders of magnitude faster than FIB, which allows cross-sectioning of whole packages.

Introduction

Here we present a new workflow that utilizes the microPREP™ picosecond laser ablation tool with the Ilion™ II broad argon beam system as a solution for extremely large area preparation with surfaces suitable for microscopy analysis.

Workflow

Figure 1. A workflow using the microPREP and broad argon beam tool to prepare the cross-section shown in Figures 3, 5, and 6.

Chip Package

A commercially available three chip package as shown in Figure 2, was used for demonstration.

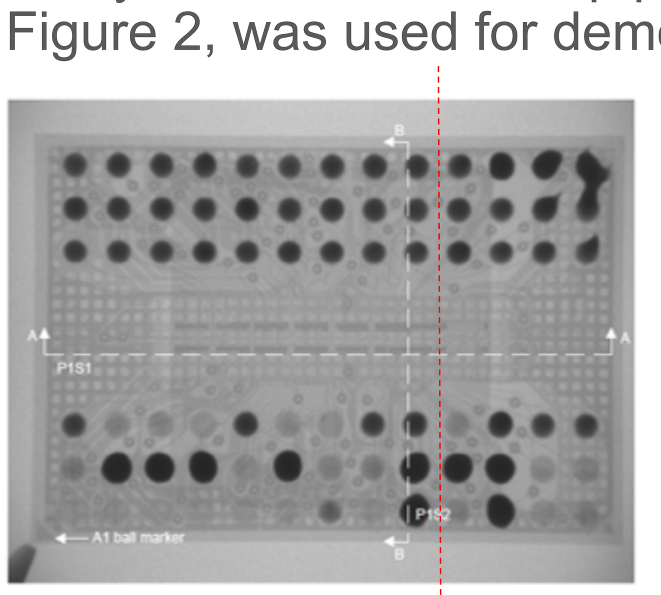

Figure 2. X-ray image of the K4AAG045WD-4CRB package with cross-section location highlighted by the red line.

The microPREP system was used to perform a line cut along the red dash line as shown in Figure 2 to cut across the whole length ~9 mm and through the thickness 760 µm of the package. The processing time of this line cut was only 15 min. Thus at the macro level, large cross-section preparation is possible with the microPREP system. There is a heat affected zone of ~1 µm from the laser. By continuing with the second step in the workflow, 1 h broad ion beam polish in Ilion system, a wide cross-section region of over 1 mm wide with excellent polishing quality is possible.

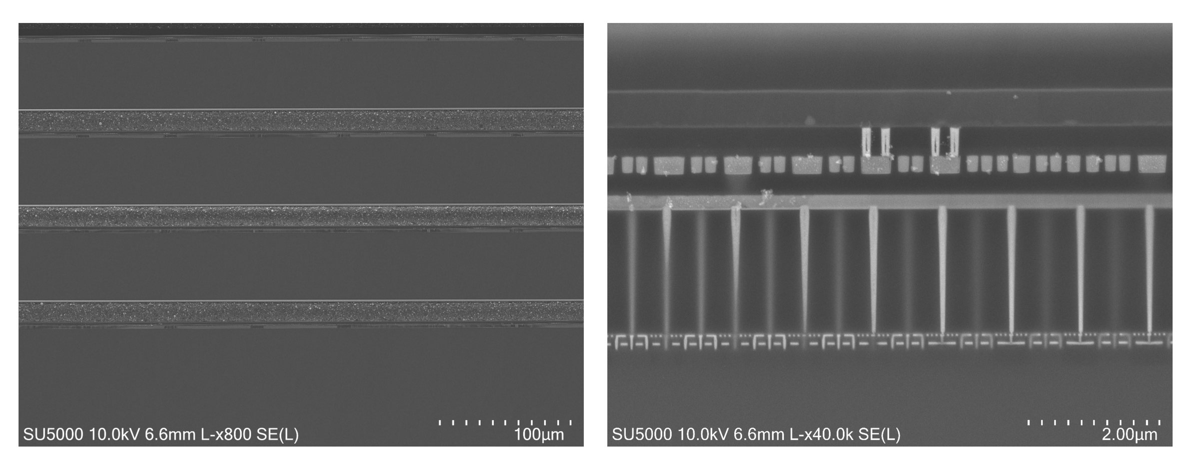

Figure 3. SEM images of cross-section of stacked chips prepared with microPREP system and then broad Ar ion beam tool at low and high magnification.

Figure 4 shows optical images of a memory die in the package. A site-specific study was performed to reveal the microstructure of through-silicon via (TSVs). By using the embedded optical microscope, the microPREP system was able to execute a line cut at the target position, ~50 µm away from the TSV array, as shown by the red dashed line. Followed by 1 h ion polishing towards the TSVs using Ilion system, a nearly perfect cross-section surface was revealed to exhibit the structure of Cu TSV array, as shown in Figure 5.

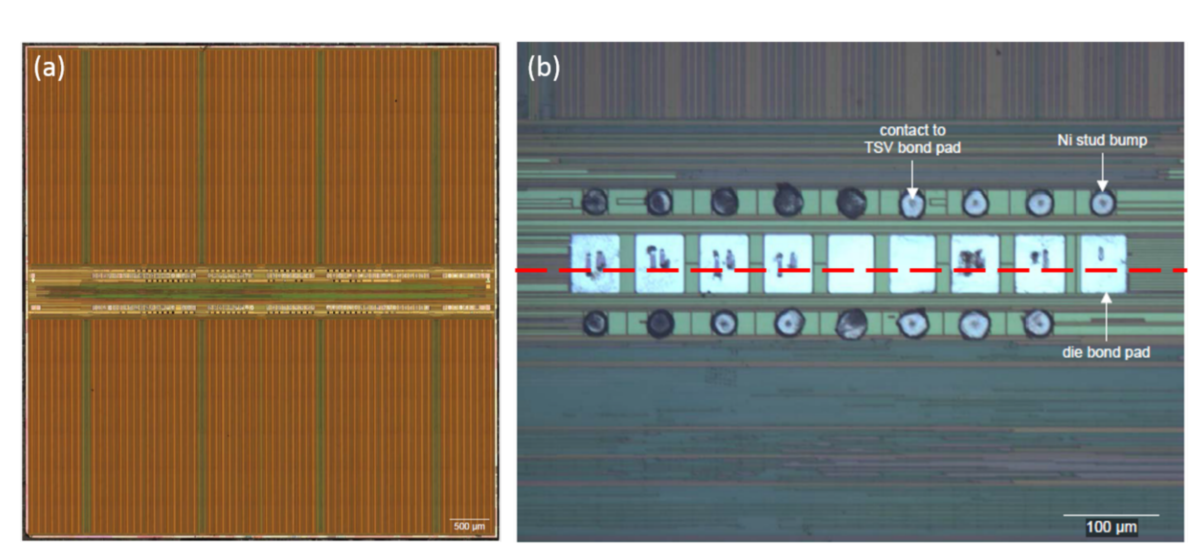

Figure 4. Optical microscope images of K4A4G085WD memory die; (a) low magnification image; (b) close-up to show the TSV bond pad.

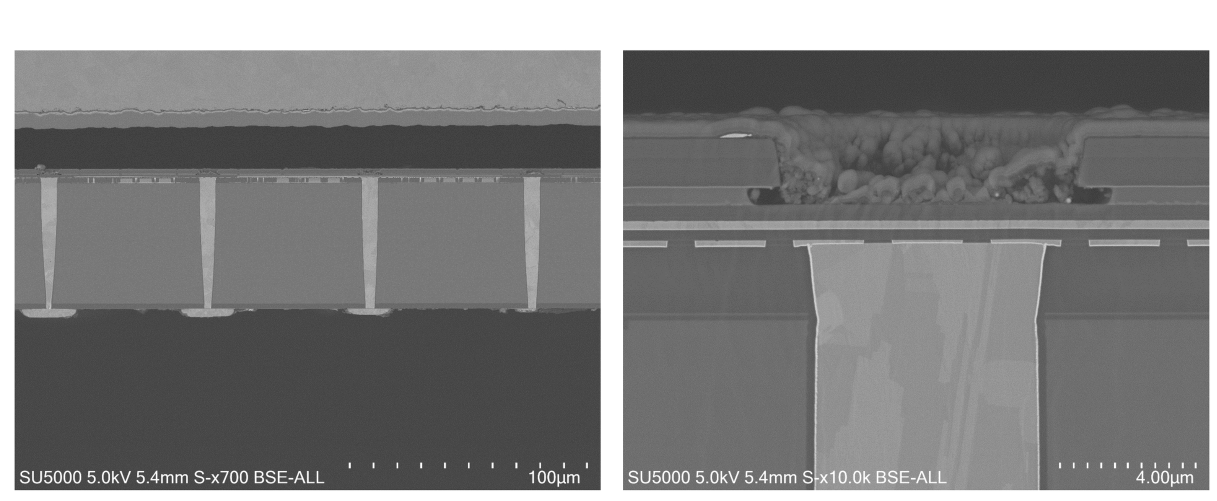

Figure 5. SEM images to show an array of TSVs and the details of an individual TSV. Grain structure can be clearly observed.

Smartphone Home Button

Home buttons are more complex than simply an on/off or function selection when viewed at the microscopic level. Preparation of a cross-section can be a challenge as the top surface is frequently a ceramic with silicon device technology buried well below. After an excursion to a shopping mall to purchase home buttons, they were cross-sectioned using the same workflow shown in Figure 1.

In this case, the microPREP system time was 45 min including slicing through the ceramic top layer (top) and steel layer (bottom).

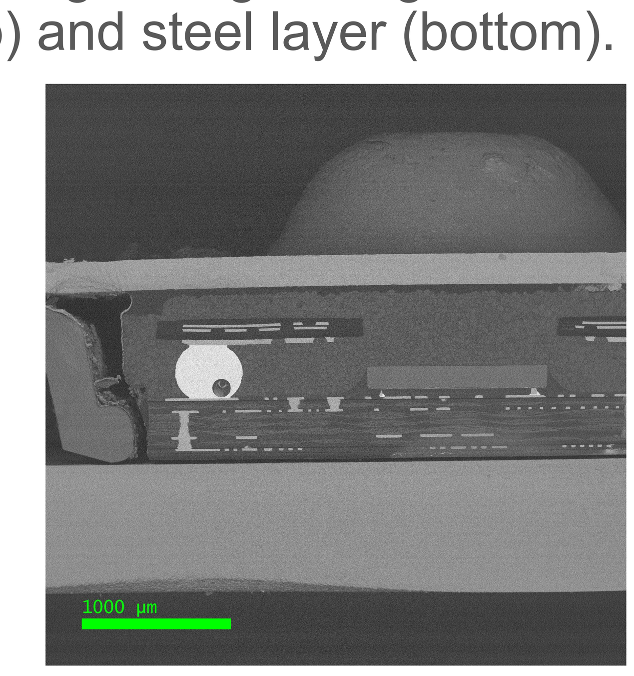

Figure 6. Low-magnification backscattered electron (BSE) image of a mobile phone home button after the workflow described in Figure 1. The cross-section is shown mounted on an Ilion II blade. The complete device was cross-sectioned 6 x 1.4 mm (L x D) thick in the microPREP system in 45 min. The Ilion II system’s cross-sectional area is ~2 x 1.4 mm.

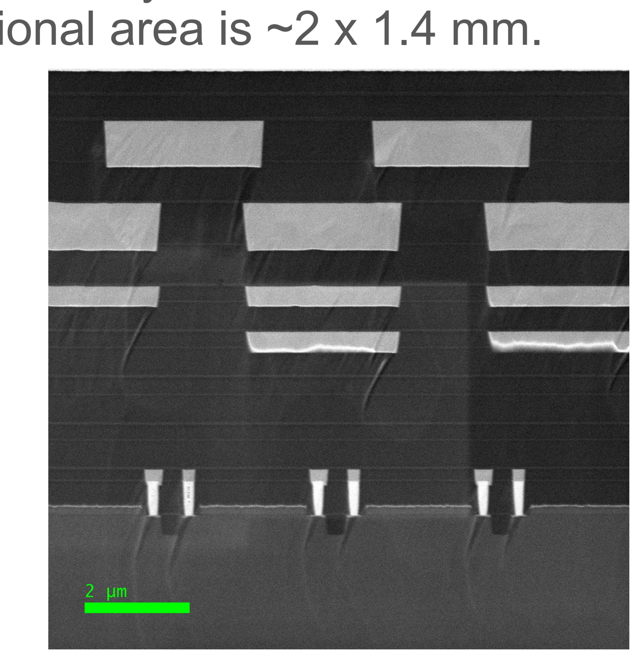

Figure 7. BSE image of the transistor structure in the mobile phone home button. This region is ~600 µm below the ceramic and resin layers and ~600 µm above the metal base of the button. Both cut with the workflow described in Figure 1.

Conclusion

The impact of “More than Moore” on the continued trend for faster, smaller, and more complex communication and computing devices, stresses the need to consider alternative toolsets for materials characterization. A FIB, of any type, is too slow to section and polish interfaces measured in mm’s by a mm in thickness. At the same time as preparing these large interfaces, the surface quality must be maintained.

One possible replacement workflow is based upon the use of the microPREP picosecond laser with the Ilion broad argon beam tool to increase the area by >1000 fold to observe the cross-section of advanced packages while maintaining an interface suitable for characterization at the nanometer scale.

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