NANO MECHANICAL AND MICROSTRUCTURAL INVESTIGATION OF DAMAGE MECHANISMS IN COPPER WIRE BONDS

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Thick Copper wires and thick Copper (Cu) metallization technology has proven reliable and robust for Silicon semiconductor modules that operate at temperatures below 175°C. However novel wideband gap semiconductors utilizing Silicon Carbide, will outperform standard Si semiconductors. For these devices, set to operate above 200°C, the most suitable interconnection is Cu. This work aims to study the reliability of the novel Cu wire/metallization interface at temperatures above 200°C. The goal is to elucidate the degradation behavior of these bonds through the understanding of the effect of thermomechanical stress resulting from the difference of CTE during cycling. And ultimately to further improve their reliability for higher temperature use.

The biggest structural change in the configuration of Cu-based wire interconnections is the novel Cu metallization much thicker than the previous Al ones. This thickness makes it nearly impossible to observe the microstructural evolution of either wire or metallization using in-situ TEM techniques. However, high resolution EBSD and in-situ SEM nano indentation, render the mechanical properties and microstructural properties of these wire bonds accessible at different scales. The in-situ SEM nano indenter allows to easily locate the region of interest that might be difficult to access without the high-resolution imaging of the SEM. The in-built software allows us to extract both H and E maps as well as perform several data analysis techniques such as k-means. First, high-speed nano indentation map with large indent spacing is performed over a large area in the wire and the metallization to compare the mechanical properties of the two regions. The large indent spacing results in limited spatial resolution in the H maps but gives a large statistic of the mechanical properties of the wire and metallization before and after cycling. Second, by adjusting the indent spacing to 1µm, the resolution improves and a clear contrast in mechanical properties of the interface region can be seen from the H maps. A peak in hardness at the interface results from dispersed ultra-fine grains. The origin of these very small grains is yet to be understood, plastic deformation during the wire bonding process or strain accumulation during power cycling.

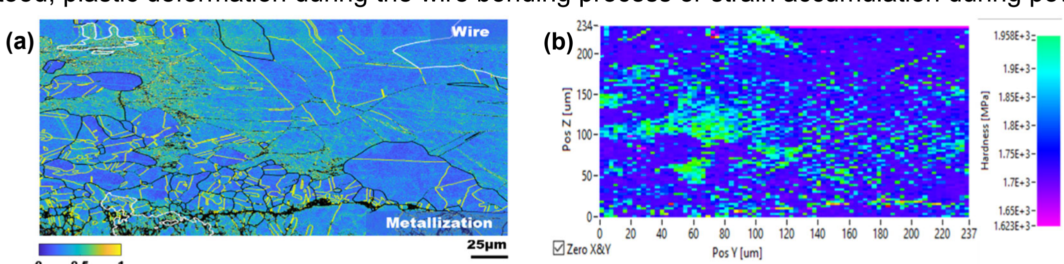

Figure 1 (a) The KAM (Kernel Average Misorientation) map (b) is the corresponding H map of (a). The indent spacing and depth are 3µm and 100nm respectively. The region of higher average misorientation corresponds to the peak of hardness in the H map. At this resolution for both the images the microstructural and mechanical properties of the interface are not well described due to the fine size of the interface grains.

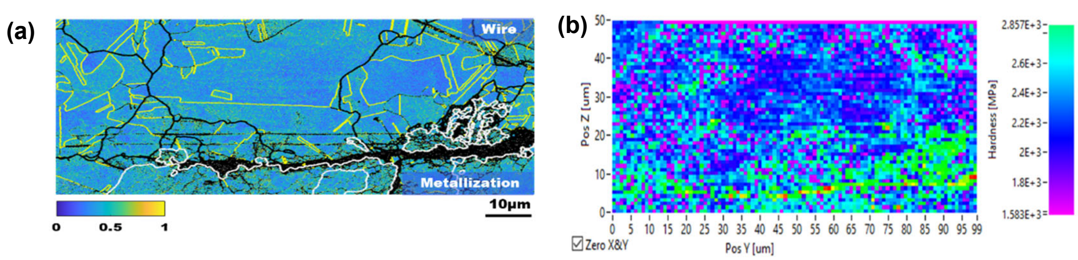

Figure 2 (a) The KAM map at higher resolution b) is the corresponding H map of (a) of a region around a crack tip. The indent spacing and depth are 1µm and 50nm respectively. A clear contrast in the mechanical properties of the region is seen in the H map as compared to the KAM map around the crack tip region