Shear tests of BEoL interfaces with in-situ SEM imaging

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The need for measuring or ranking the adhesion between thin dielectric caps (< 50nm) and metal layers is part of the failure mode and effect analysis to be addressed when developing new Back-End of Line (BEoL) stacks. The mechanical test suitable to compare different interfaces should both be capable to promote the failure mode of interest and provide a figure of merit sensitive to the differences in adhesion energy and/or interfacial strength. Testing dedicated structures directly on the true device is also a relevant added value, when there exists a perspective to include such characterization into automated quality control.
In this view, the shear test was identified as an eligible test method: this consists in pushing a flat-faced chisel against the free edge of a test structure (from now on, the *button*), the latter constrained at the interface of interest. The test ends when the button no longer offers lateral reaction to the movement of the chisel and the typical figure of merit is the maximum lateral load achieved during the test (from now on, the *critical load*).

The shear test is very common in the qualification flow of packaging and wire-bonded interfaces [1], where the surfaces exposed on both the substrate- and the button-side suit the qualitative assessment of the failure mode. Implementing the test in the framework of BEoL stacks poses additional challenges, owed to the smaller characteristic length scale of the layers of interest [2]: in this work, the presence by design of a thicker dielectric (Silicon nitride, SiN, 500nm) on the thin dielectric cap was exploited to mill prismatic test structures using Gallium focused ion beam (FIB); test structures were milled targeting an in-plane footprint visible at an optical microscope (10x10µm), enabling relocation and successful shear tests of two Copper (Cu) / cap interfaces, using a bi-directional nanoindentation device (Hysitron TI-980, Bruker). Noteworthy, the interfaces under comparison not only featured measurable differences in the critical load, but also in the shape of the softening branches past the critical load.

While testing on standalone nanoindentation platforms is convenient in the view of potential automation and increased throughput, the assessment of failure modes relies on ex-situ observation methods, lacking deep insights into the origins of different kind of failures. For this reason, measurements were repeated using a compact nanoindenter (ZHN/SEM, Asmec) meant for installation in Scanning Electron Microscopes (SEM): a deep trench was FIB-milled on one side of the button, enabling in-situ SEM imaging during the shear test; the sequence of images revealed a markedly different extent of Cu plastic deformation for the two interfaces under comparison, suggesting a correlation between the extent of Cu plasticity before complete button shear off and the shape of the softening branches previously observed in the experimental campaign with the standalone indenter. Noteworthy, the assessment of the failure mode (*interfacial delamination* versus *cohesive Cu failure*) was itself not trivial and required relocation and transfer of the sheared button into a SEM equipped with a detector for Auger Electron Spectroscopy (AES), for shallow-depth analysis of the chemical content of the button surface exposed by the test.

In summary, this work illustrates the implementation of a shear test meant to compare Cu/cap interfaces relevant for BEoL stacks. In-situ SEM imaging is proposed as a suitable mean to gain insights in the physics of failure. These additional information enabled a more comprehensive interpretation of the load trends already accessible with standalone platforms, which in turns potentially suit automated and extensive experimental campaigns.

References
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