Focused ion beam nano-trench shape dependence on target material

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One of the major challenges of Circuit Edit (CE) applications by focused ion beam (FIB) is the perpetual down-scaling of minimum features per VLSI process technology generation. In particular, the finest feature required by FIB fabrication is a vertical electrical connection through dielectric to a minimum dimension target metal line in the chip, commonly called a "via". The sidewalls of the vias must not protrude beyond the edges of the metal line. The attainment of sufficiently narrow vias has been a major thrust in our efforts leading to 10 nm process generation CE readiness.

The vias studied involved FIB gas assisted etching in dielectric to a depth of several tens of nanometers (where a metal line would have been in a real chip). These vias were then filled with E-beam deposited metallization, to prevent additional FIB-related changes to the studied shape. The vias were elongated – representing our real vias – along a target metal routing direction, but also to minimize widening due to patterning shortcomings. The elongation enabled robust sample preparation for transmission electron microscopy, providing high resolution characterization and accurate full width at half maximum (FWHM) measurements. The FWHM of the vias determines their suitability for CE, and depends on attributes of the FIB system used. Via shape, e.g. tapering, is yet another important attribute which influences the quality of the connection.

In the large array of tests we performed, we identified a marked difference in the FWHM of vias depending on the dielectric material in which they were etched. FIB etched vias through a PECVD oxide layer and through a FIB induced deposition oxide layer differed significantly in FWHM (see Figure 1).

In this paper we present data substantiating this difference in via widths, and discuss possible explanations for this phenomenon. We believe that understanding the influencing parameters will provide useful information for both the CE community and for FIB nano-machining application developers.

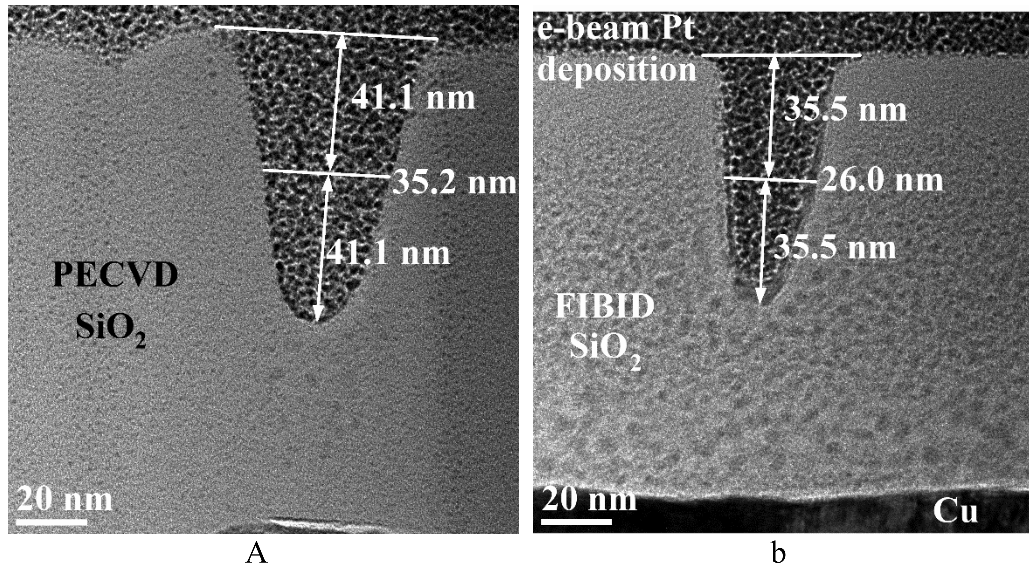

Figure 1: Side by side via comparison: TEM bright field images of typical gas assisted etched vias through (a) PECVD SiO_2 layer and (b) through FIBID oxide layer. Vias were etched using the same beam current (1 pA) and same FIB recipe. The via FWHM and profile of the "through FIBID oxide" is consistently ~30% narrower in comparison with the vias through PECVD oxide.