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A Comparison of TSV Etch Metrology Techniques

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Summary

We use three metrology techniques, vertical scanning interferometry (VSI), confocal chromatic microscopy (CCM), and time domain optical coherence tomography (TD-OCT), for depth measurement of through-silicon vias (TSVs) of various cross sections and depths. The merits of these techniques are discussed and compared.

Introduction

While sales of semiconductor equipment broke a new record this year, many metrology needs should be addressed to support the development and production of electronic chips based on “More than Moore” scaling. Among these scaling approaches, 3D integration based on TSVs offers superior integration density and reduces interconnect length/latency. Measurements are needed to evaluate the depth uniformity of etched TSVs. Indeed, upon metal filling, geometrical variations of TSVs can affect Cu nails coplanarity and can warp the wafer, resulting in a low stacking yield. Measuring the depth of TSVs is an increasingly challenging task as the diameter of many TSVs has now shrunk to only a few microns.

Method

A lithography mask comprising circular and square patterns of diameter/side 3, 5, 7, and 9 μm was used to etch two silicon wafers at different depths, resulting in TSVs further referred to as shallow and deep TSVs. The TSVs' aspect ratio (ratio of depth to diameter, or ratio of depth to side, for circular or square TSVs, respectively) varied approximately in the range 1 to 20.

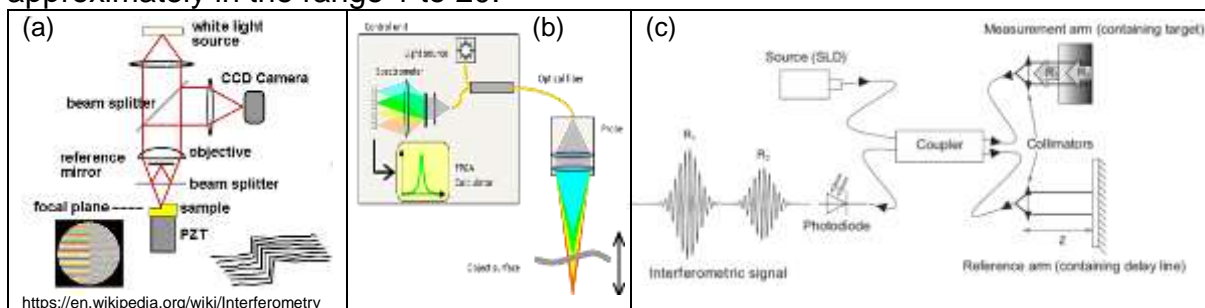


Fig. 1. Metrology techniques applied to TSV etch metrology: (a) Vertical scanning interferometry (VSI) , (b) Confocal chromatic microscopy (CCM), (c) Time domain optical coherence tomography (TD-OCT)

VSI measurements were performed on a UnitySC tool from the NST series with a x50 Mirau objective lens scanned over up to 100 μm in steps of 40 nm. The same tool incorporated a TD-OCT device from Fogale Nanotech operating at a wavelength of 1300 nm with a FWHM spectral width of 110 nm [1] and focused with a x50 microscope objective.

Confocal chromatic measurements were performed on a UnitySC tool from the 4SEE series offering rapid 3D raster scanning with a line of 192 measurement points.

Results & Discussions

Fig. 2 shows examples of metrology results by the three methods under investigation while fig. 3 summarizes all the depth measurement results. SEM depth measurements from cleaved shallow TSVs are also shown in fig. 3 and used as benchmarks.

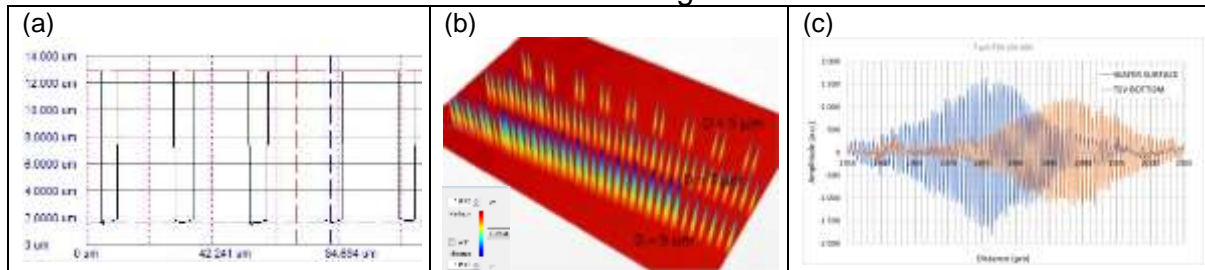


Fig. 2. Examples of metrology results in shallow TSVs: (a) VSI on a circular TSV 7 μm in diameter, (b) CCM height map on square TSVs with side ranging from 9 to 3 μm (3 μm not detected), (c) TD-OCT interferograms from the upper surface and the bottom of a circular TSV 7 μm in diameter.

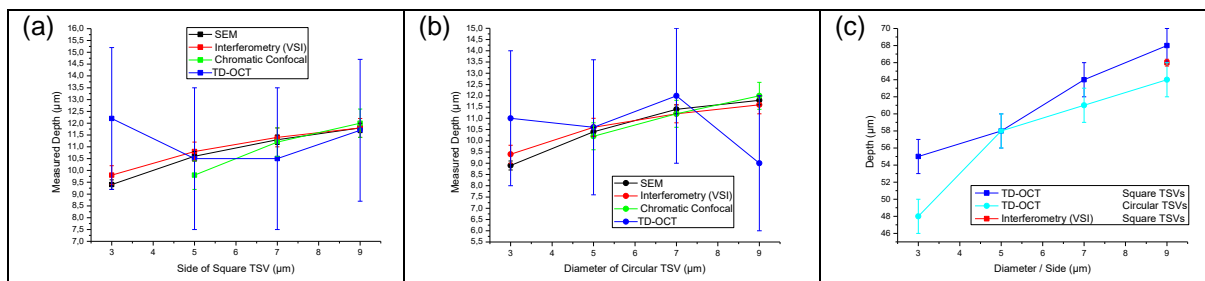


Fig. 3 Depth measurements by SEM, VSI, CCM and TD-OCT vs side or diameter for (a) square shallow TSVs, (b) circular shallow TSVs, and (c) square and circular deep TSVs (only TD-OCT and to a lesser extend VSI were able to perform the measurements on deep TSVs.)

VSI provided measurements in excellent agreement with the SEM for shallow TSVs but failed to return sufficient signal from deep TSVs (except for the square TSV with 9 μm side). CCM produced results in good agreement with the SEM in record speed but only for shallow TSVs. It was unable to measure the narrowest TSVs (3 μm in diameter or side). TD-OCT was the only method able to resolve the depth of both shallow and deep TSVs. Its accuracy is still under evaluation and improvement. The depth of the shallow TSVs is close to the coherence length of the TD-OCT. It results in interferences between top and bottom surfaces which affect the measurement accuracy. We are developing a model-based approach which will correct for this effect.

Conclusions

VSI offers high accuracy, CCM offers fast scanning, but TD-OCT is superior to these techniques for deep TSVs. We are further investigating and improving its capabilities.

Acknowledgements

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Reference

[1] D Allia et al., P46, *International Microelectronics Assembly and Packaging Society (IMAPS)*, 14th International Conference and Exhibition on Device Packaging WekoPa Resort and Casino Fountain Hills, Arizona USA 2018