X-ray CD: Powerful metrology solution for HAR memory structure

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Introduction

As memory chip manufacturers move to more advanced technology nodes, the features that need to be etched and filled are increasingly narrow and have higher aspect ratios. High aspect ratio (HAR) etch continues to be the most critical and difficult step in the entire flow. These HAR structures have micron level depths with angstrom-level requirements for precision, which makes it extremely challenging for metrology to provide robust, non-destructive, and accurate in-line process control solutions. To solve these problems, we investigated 3 different CD-SAXS world leading suppliers and demonstrated the powerful x-ray tool capability. X-rays can penetrate the structure and provide information such as tilt, CD vs depth, overlay shift, twisting and more with the demanded accuracy, for HAR samples which are few microns deep and even with multiple tiers. In this poster, we will provide introduction of x-ray CD solution with different tool sets. The correlation results look promising between different tools and with reference metrology.

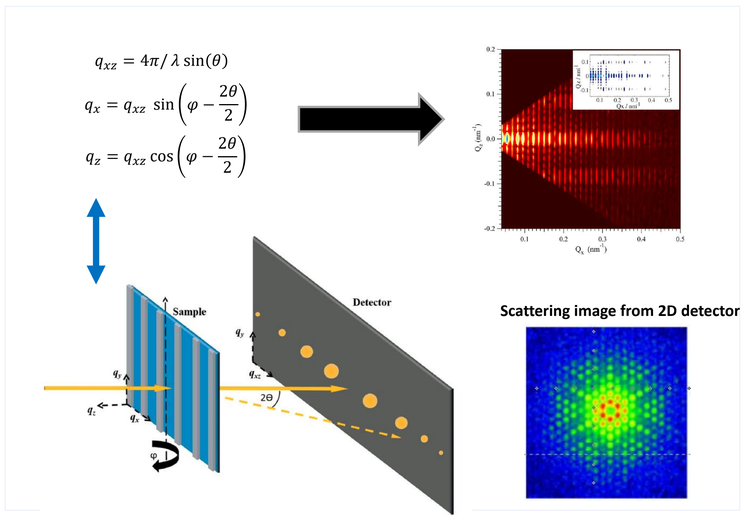

Figure 1. CD-SAXS method utilizes the variable-angle transmission scattering from a small beam size to provide detailed shape and dimensional data with sub-nm precision. It is non-destructive.

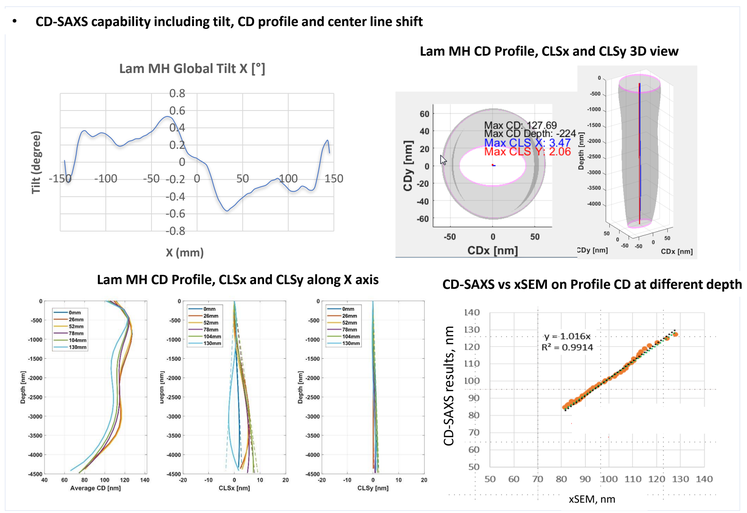

Figure 2. 1-Tier 3D NAND post memory hole global tilt and profile measurements using Lam in-house CD-SAXS tool. Tilt, center-line shift, and CD vs. depth is obtain with excellent correlation to xSEM.

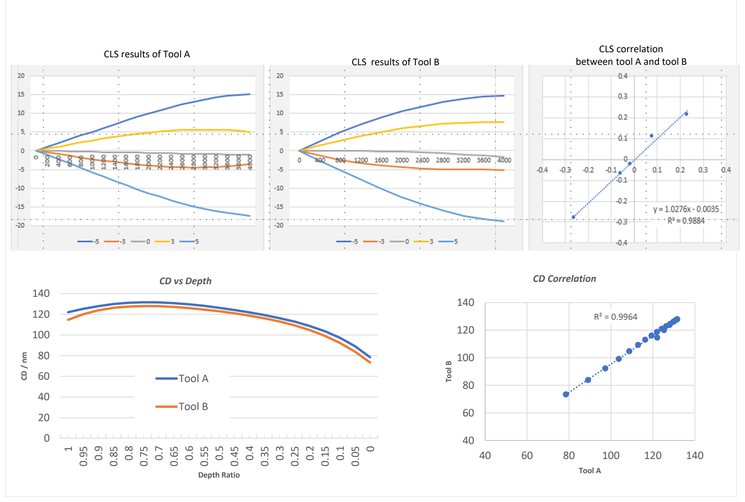

Figure 3. 1-Tier 3D NAND post memory hole global tilt and profile measurements using different CD-SAXS tools. Tilt, center-line shift (CLS), and CD vs. depth is obtain with excellent correlation to xSEM.

Methods

The methods we used is critical dimension small angle x-ray scattering (CD-SAXS). The incoming X-ray beam is incident on the sample with a 2D detector that collects the intensity of the diffracted beam as a function of the diffraction angle (2θ). As the sample is rotated around ϕ, intensity dependence on vertical features increases, which is illustrated in Figure 1. Benchmarking was done to determine performance of commercially available CD-SAXS tools. Current in-house capabilities are capable for both fast global tilt and profile measurements. The profile mode can measure kink, max bow, center line shift, multiple-tiers and other features with depth up to 15um. Both whole wafers and coupons can be measured. CD-SAXS provides non-destructive solution of 3D-profile with better repeatability/precision comparing to both xSEM and CDSEM.

Results & Discussion

Samples tested include hard mask open (HMO) etch, 1-tier memory hole (MH) etch, 2-tier MH etch, and DRAM structures. In this poster, the results from Lam internal HAR samples are discussed. Figure 2 shows our inhouse CD-SAXS capability on Lam internal 3D NAND samples. The data includes global tilt, 3-dimensional profile and center line shift (CLS), which shows tilt amplitude and direction at different etch depth. The correlation to reference is up to 0.99. We also tested CD versus Depth and CLS on 1-Tier 3D NAND post memory hole measured on different CD-SAXS tools, using Lam internal HAR samples. Results from two different tools are shown in Figure 3. The correlation between different tools are up to 0.99. Overall, CD-SAXS is capable of measuring tilt of multi-tier stack, CD profile, joint displacement, litho overlay.

Conclusions & Next Steps

This work give us great confidence on CD-SAXS as non-destructive method providing 3D-NAND memory hole profile, CLS and global tilt information with sub nanometer precision. In the next few years, we expect to see significate improvement in both performance and throughput. We will keep investigating this method on more and more challenging applications.

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