Advances in CD-Metrology (CD-SAXS, Mueller Matrix based Scatterometry, and SEM)

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ABSTRACT

Scanning Electron Microscopy (SEM) has been a mainstay of critical dimension (CD) metrology since the inception of integrated microelectronics, due to its inherent high resolution capability and relative ease of interpretation. However, as device dimensions continue to shrink, and non-planar devices become integrated into process flows (e.g., finFETs), the need to identify and develop successor technologies becomes essential. Here, we report progress on the development of two innovative technologies proposed for CD measurement, and assess their viability for high volume manufacturing applications. Finally, we describe recent efforts to extend the life of conventional CD-SEM.

Small Angle X-ray Scattering (SAXS) also offers Angstrom-level resolution, is non-destructive, and requires no additional preparation steps. Performed in either transmission or reflection mode, this method is particularly suitable for arrayed structures and non-planar devices. Whereas direct imaging methods provide a complete description of a single measurement site, SAXS probes a comparatively large area containing many sites, and effectively provides information on feature dimensions and the statistical variations within the sampled. The chief limitation to implementing CD-SAXS is throughput, gated by x-ray source brilliance. Conventional x-ray tube and rotating anode sources do not have the correct combination of brightness and stability required to obtain rapid, consistent measurements. Recent innovations in x-ray source technology, including plasma and liquid metal based sources, have shown promise for making CD-SAXS a viable HVM method.

Scatterometry methods offer yet another attractive approach. Advances in the optical components and simulation software enable one to obtain most of the sixteen components of the Mueller Matrix for each wavelength of light instead of the typical $\Psi$ and $\Delta$. This is great importance when measuring highly anisotropic 3D scatterometry test structures.

Finally, it is worth considering the efforts to extend the life of CD-SEM. A series of advances such as drift correct frame averaging and 3D Monte Carlo models that improve metrology for nanoscale features are all under consideration. These improvements push CD-SEM resolution closer to its theoretical limits. Additionally, the use of contrast transfer functions (CTFs) as an improved means for achieving tool matching and assessing tool performance is considered. When an image is collected from an ideal test specimen, such as a high resolution Fresnel Zone Plate or a pseudo-random dot array, the CTF can be used as a measure of the fidelity with which specimen topography is represented in the recorded signal, as a function of spatial frequency. Tuning SEM parameters to manipulate the CTF provides a richer feedback mechanism than simply using nominal resolution and signal-to-noise ratio.