Development of algorithms and modeling tools for low-energy CD-SAXS measurements

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With the continued miniaturization of electronic components over the last few decades, there is a rising need for new in-line metrology techniques capable of characterizing component with sub-nanometric resolution. While microscopies such as SEM or AFM are widely spread and used for such measurements, they are reaching their resolution limit. CD-SAXS has been developed over the last decade and shows promising results [1]. However, it is currently not available in lab-based settings (except for High Aspect ratio structures) and requires a synchrotron to go across a 750 µm-thick Si wafer.

Based on the progress of low energy x-ray sources and more precisely High Harmonic Generation sources in recent years, measurements with such source could be in reflection geometry [2]. The use of low energy X-rays allows the use of a relatively high incident angle (>15°). Therefore, the footprint of the beam on the sample is viable for measurements on small patterned area (50x50 µm2).

Promising results were obtained with HHG sources [3, 4]. However, the different interaction between soft x-rays and matter requires us to rethink all the simulation mechanisms. Indeed, hard x-rays approximations like the Born Approximation (BA) and the Distorted Waves BA (DWBA), neglecting absorption phenomena, are not valid anymore. To illustrate those limitations, we propose to compare simulations obtained with BA and DWBA with the results yielded by a Maxwell solver that's used to solve the electromagnetics equations directly.

We will present the results of CD-SAXS and GISAXS simulations obtained with JCM [5] software. JCM enables us to illustrate what's hapenning in both near field and far-field. Then, we will compare the results obtained with the BA and DWBA with the Maxwell solver and discuss the limit of validity of the BA and DWBA approximation with x-ray energies.

Finally, we will illustrate the role of the refraction and absorption phenomena in near field results to explain the final difference between the simulations and discuss the conditions in which the CD-SAXS and GISAXS simulations required maxwell solver.

References

[1] D. F. Sunday, et al., Three-dimensional x-ray metrology for block copolymer lithography line-space patterns, J. Micro. Nanolithogr. MEMS MOEMS 12, 12 (2013)
[2] J. Seres et al., « Source of coherent kiloelectronvolt X-rays ».
[3] V. Soltwisch et al., « Reconstructing detailed line profiles of lamellar gratings from GISAXS patterns with a Maxwell solver ».
[4] C. Porter et al., "Soft x-ray: novel metrology for 3D profilometry and device pitch overlay"
[5] JCMwave