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ESRF The European Synchrotron

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CD-SAXS : measurement of critical dimensions and morphology of nano-objects

Critical Dimension Small Angle X-ray Scattering (CD-SAXS) is a non-destructive technique allowing the morphological characterisation of line-grating nano-objects. Features such as height, line-width, pitch size (period), sidewall angle (β) and line-edge roughness can be measured with very high accuracy and precision.

Context

Ever increasing transistor scaling is bringing technology nodes to impressive sub-5 nm channel lengths in the near future. Manufacturing these devices require high-resolution lithography patterns, with line widths (also called critical dimension) in the order of few nanometres. These critical dimensions (CD) must be precisely and accurately measured. Conventional metrology is already facing several limitations in terms of resolution.
Measuring CD with the Small Angle X-ray Scattering (CD-SAXS) could help the semiconductor industry keep pace with transistor scaling.

The challenge

Critical dimension (CD) is the absolute size of a minimum feature in an integrated circuit. For advanced technology nodes, CD is typically the line width corresponding to lithography patterns and is in the order of few nanometres. Controlling the morphology of these features is a serious challenge. Measuring the SAXS pattern coming from these line grating samples could be a solution. To measure this patterns, X-rays must to go through the sample. X-ray beam must be very small, of high energy and intensity (brilliance). The ESRF beamline BM05 is the ideal solution to perform CD-SAXS measurements.

The results

The very high spatial resolution allowed to perform CD measurements and morphological features for technology nodes smaller than 5nm. Fig. 1 Illustrates the parameters of the line-grating pattern that can be measured by CD-SAXS technique:

- Height H
- Period (pitch size) L
- Line width ω_0
- Sidewall angle β
- Line edge roughness (if any) σ

CD-SAXS is a powerful enabler of future electronics with applications in benchmarking for product and process development.

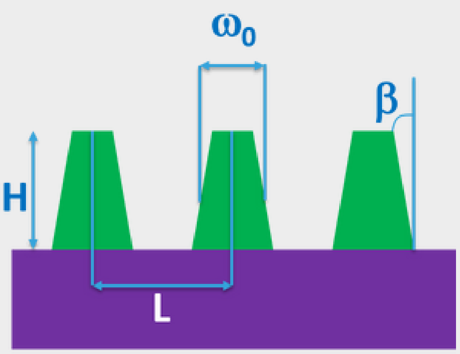
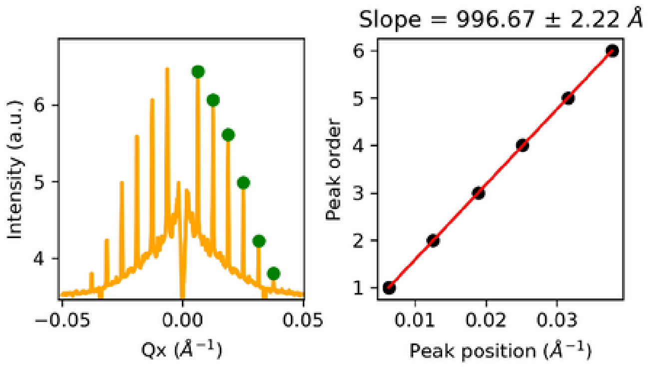
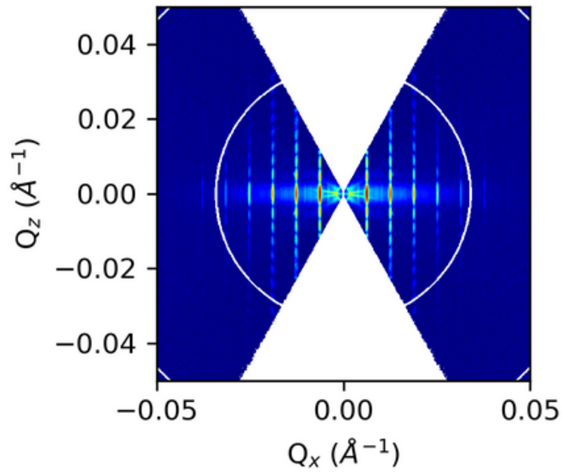
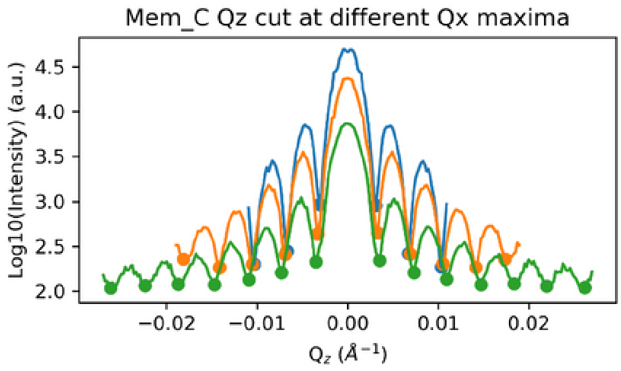


Fig. 1





- Raw data measurement
- CD-SAXS map reconstruction
- Extraction of Qx, Qz profiles
- Critical dimensions



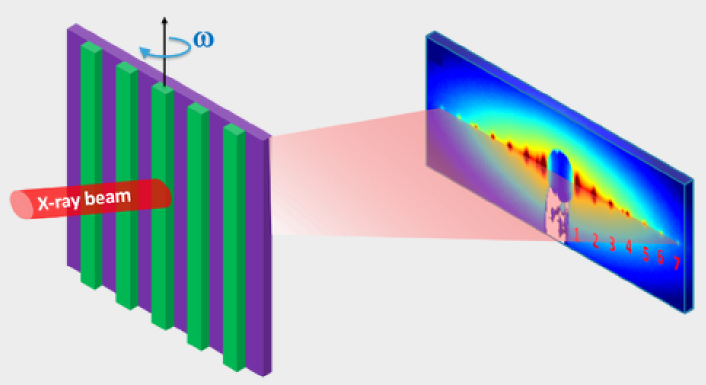
Conclusion

CD-SAXS measurements performed at the ESRF allow for a fast and accurate measurement of critical dimension with sub-Angstrom precision.

Because of the very high flux provided at ESRF beamline BM05, very fast acquisition time is possible with high throughput, limiting the costs of the experiment as well as time-to-results. In addition, No particular sample preparation is required on a patterned wafer. The technique is non destructive and whole sample statistics can be obtained. The combination of these factors makes a strong case for the systematic use of CD-SAXS as a cost effective and high-quality manner to characterise line gratings.

The technique

- Strong synchrotron beam at high energy is focused on a small spot which illuminates the sample area (hundreds of micrometres).
- A 2D detector is placed behind the sample to collect SAXS pattern data coming from the sample while it rotates.



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