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# Small Angle X-ray Scattering applications for advanced metrology in microchips manufacturing

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**Abstract.** The microelectronics environment keeps evolving towards smaller feature sizes in components to increase their efficiency and their density of integration. In order to meet with such downsizings and new exigencies, the whole process chain of the manufacturing must overcome technological and physical challenges. This chain contains numerous contributors, from the components designers that have to create ingenious structures to lithographs that print the stacks, etchers who have to go through new materials with high selectivity and anisotropy and metrologists who measure feature sizes with continuously more demanding precisions and accuracies.

Our work takes place in this last section. We evaluate Small Angle X-ray Scattering (SAXS) ability to probe stacks of silicon line gratings adapted to requirements of advanced technologies. By measuring the diffraction pattern at different angles of rotation along the length of the lines, we rebuild a 2-Dimensional map of the reciprocal space. Data treatment based on inverse problem resolutions then yields a full 3-Dimensional reconstruction of the probed structure. This allows us to probe key parameters of the lines such as the so-called Critical Dimension (CD, here the width at half-height), sidewall angle, height and overlay (alignment error between two stacks). In a first study, we benchmarked the SAXS shape reconstruction of line gratings against several techniques: Scanning Electron Microscopy (SEM), Optical Critical Dimension (OCD, based on optical scatterometry) and Transmission Electron Microscopy (TEM). We found out that SAXS sub-nanometric resolution makes it a good candidate for reference metrology in advanced technologies, with accuracy and precision adapted to future requirements.

We then apply the same acquisition and data treatment procedures on several samples of line gratings with graduating programmed overlays. The results are compared to those obtained with commonly used and well know techniques such as SEM contour-based overlay and critical dimension measurement, OCD, Image-Based Overlay (IBO) and Diffraction-Based Overlay (DBO). The reconstructed structures are compared to profiles obtained with TEM and 3-Dimensional Atomic Force Microscopy (3D-AFM). We also apply an analytical SAXS overlay extraction method based on the one enlighten by the tool manufacturer KLA in their patent US 9,885,962 B2, which consists in measuring variations of intensity minima along the Bragg rods in the presence of overlay. From the differences between these multi-scale techniques, we can conclude on SAXS high potential to become a reference for highly accurate CD and overlay measurement.

**Keywords.** Microelectronics, metrology, Small Angle X-ray Scattering (SAXS), CD, overlay, benchmark.

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