Transmission Small Angle X-ray Scattering (tSAXS) for Overlay Measurements

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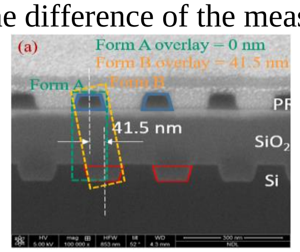
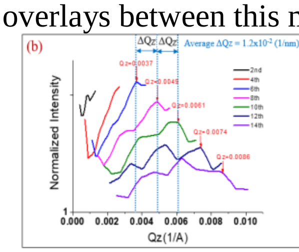
ABSTRACT

This study aims to develop Transmission Small Angle X-ray Scattering (tSAXS) to measure overlays for ‘After Development Inspection (ADI)’ in advanced semiconductor manufacturing processes. DBO (Diffraction-Based Overlay) technology is currently the main overlay measurement technology used for the ADI. One of the critical challenges for the DBO technology is the insufficient diffraction signals obtained effectively from the buried overlay marks (the alignment grating structure). As a result, the precision of the overlay measurements by the DBO is highly limited in the advanced technology node such as N3. Compared to DBO technology, the tSAXS can be used advantageously to non-destructively penetrate and measure the critical dimensions of the surface layer and multilayer grating structures below the surface with high spatial resolution.

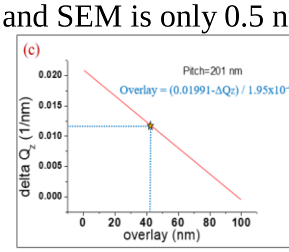
The overlay is expressed as the ‘shift’ of the multilayer grating structures, as shown in Figure (a). In tSAXS measurement, the shift and the two misaligned gratings are, then, treated as a basic ‘form’ of scattering cross-section for deciding the overlay. Scattering signals with different incident angles from the form are resolved to obtain the shift, which is the overlay, with known grating parameters. To resolve the overlay or shift, full 2D scattering patterns are obtained first from tSAXS measurement with a range of incident angles from 2 to 12 degrees. The even-order scattering signals from 2nd to 14th are obtained after data reduction from the 2D scattering patterns as shown in Figure (b). Based on Figure (b), ΔQ_Z is determined by the position differences of the highest scattering peaks in Q_Z for any of the two adjacent even-orders. The ΔQ_Z also represents the shift or the overlay of the two gratings. With known grating dimensions for the two gratings, a linear curve can be established as shown in Figure (c), according to the theoretical simulations. Based on the linear curve and the ΔQ_Z from experimental results, where the average ΔQ_Z is 1.2×10^{-2} (1/nm), the actual value of the shift or the overlay is obtained as 41 nm. The difference of the measured overlays between this method and SEM is only 0.5 nm.



Figure(a): Overlay structure



Figure(b): Scattering signals



Figure(c): Linear curve