Intensity Enhancement of Transmission Small Angle X-Ray Scattering for Nanostructure Measurements

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Transmission SAXS (tSAXS) has been identified as a potential solution for measuring nanoscale features by interrogating structures with sub-nanometer wavelength X-ray radiation. Based on the spacing of diffraction peaks alone the pitch can be readily extracted from the tSAXS scattering pattern. The line width of individual structure can be extracted from the envelope function of the scattering intensity. An enhancement grating with its linewidth and pitch in commensuration with those of the target grating is positioned within the effective longitudinal coherence length of the incident X-ray from the target grating. Figure 1 shows that the transmitted Small X-ray Scattering (tSAXS) is applied for measuring a patterned CD- the target grating (shown in one-dimension).

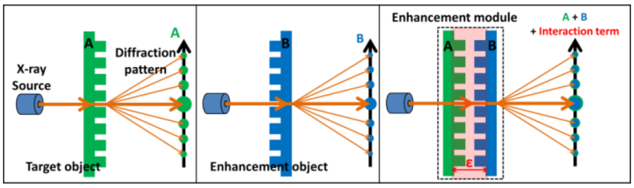

Figure 1. Illustration of transmission Small Angle X-Ray Scattering.

The scattering intensities from the target grating can be described as:

$$I \propto \Delta b_1^2 \times F_1^2(q) \qquad (1)$$

where Δb_1^2 is the contrast factor of the target grating and its value is rather small as for most nano-patterns. An additional pattern- an enhancement grating with strong scattering cross section, as shown in Figure 1, is added into the path of the transmitted SAXS adjacent to the target grating. Upon this weak scattering grating (the target grating) a strong scattering grating is placed within the longitudinal coherence length ε of the incident X-rays, as shown in Figure 1. The observed scattering intensities now become

$$I(q) \propto |\Delta b_1 \times F_1(q) + \Delta b_2 \times F_2(q)|^2 \qquad (2)$$

where the subscription 2 denotes the enhancement grating with a strong scattering contrast factor.

For simplicity both the target and the enhancement gratings are chosen to have a rectangular cross section. Since all the diffraction spots appeared along q_x with $q_y = 0$, the function $F_i(q)$ can be replaced by $F_i(q_x)$ and explicitly the Eq. (2) can be expressed as:

$$I(q_x) = \Delta b_1^2 \times F_1^2(q_x) + \Delta b_2^2 \times F_2^2(q_x) + 2\Delta b_1 \Delta b_2 cos(q_x \eta)|F_1(q_x)F_2(q_x)| \qquad (3)$$

where $2\Delta b_1 \Delta b_2 cos(q_x \eta)|F_1(q_x)F_2(q_x)|$ is the interaction term between target grating and enhancement grating and is the origin of signal enhancement over $(F_1(q_x))^2$

The resultant scattering intensities comprise the enhanced signal from the target in addition to what contributed by the target and the enhancement gratings themselves. With a target grating made of silicon and the enhancement grating made of aluminum with a tall structure, an enhancement factor of 44 times was observed. By selecting high atomic number materials for the enhancement gratings this enhancement factor is expected to increase further.