At Wavelength diffuse Scatter of EUV Optics

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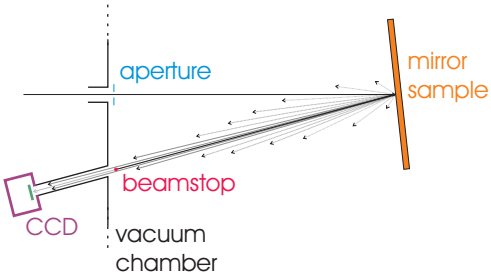
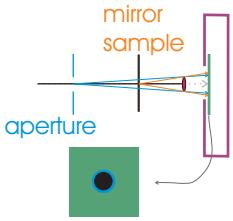
Introduction

With EUV lithography maturing, further development of EUV multilayer mirrors requires more sophisticated measurements. High accuracy reflectometry remains an indispensable tool to assess reflectivity and multilayer wavelength. The measurement of the diffuse scatter outside the specular reflex is a powerful tool for the characterization of the surface topology. Using PTB's reflectometry facility enhanced by an additional EUV sensitive CCD camera as detector, PTB is able to perform diffuse scatter measurements at the same sampling spots as the reflectivity measurements. The incident beam can be collimated to better than 200 µrad and its scatter halo is well below 10^{-5} relative intensity at an angle of 1.7 mrad. We achieve 10 µrad angular resolution in the detection and can cover about 12 orders of magnitude in signal intensity from the specular peak to the lowest diffuse scatter intensity. Due to the low divergence of the incident radiation we were able to resolve quasi-periodic structures in the scatter, corresponding to spatial roughness frequencies in the range of 100 µm (100 µrad scattering angle at 13.5 nm). As an example, we show data from our reference mirrors used for monitoring the measurement stability of our reflectometer. They were coated by Fraunhofer IWS in 2001.

Measurement Scheme

The beam enters the experiment and is formed through the aperture. The mirror sample under test sits on a goniometer for alignment. By changing the angle of the mirror, the specular and/or the scattered light is directed into a CCD. If necessary, a beam stop can be employed to cut out the specular beam for increased sensitivity for the scattered light.

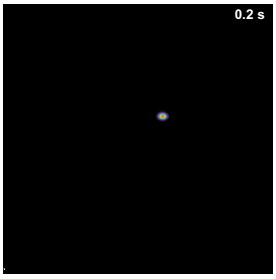




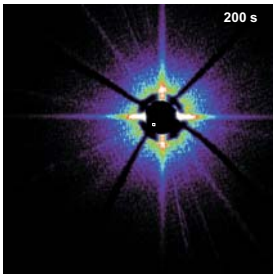
Shadows as seen on CCD

The beamstop on the CCD pictures shown exhibits a central completely black shadow and a partial shadow around the central shadow. These are different shadows due to different distances from scattersource to beamstop, the partial shadow beeing due to scatter from the aperture whereas scatter from the sample has a closer sourcepoint and therefore is visible outside the partial shadow.

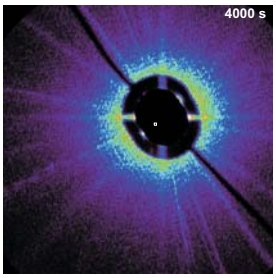
Normal incidence small angle EUV scattering

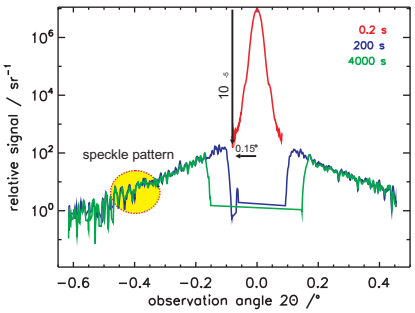


specular reflected beam

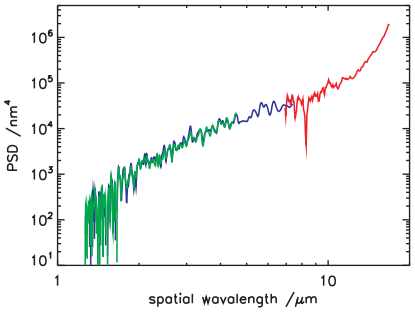


diffuse scatter with central beamstop





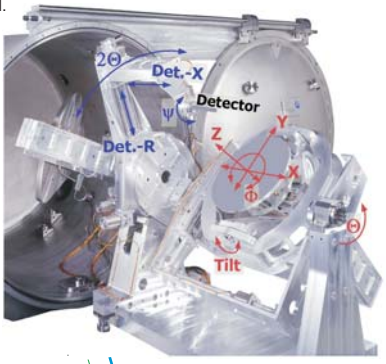
Angle resolved intensity reflected off the sample. Data derived from CCD pictures on the left.



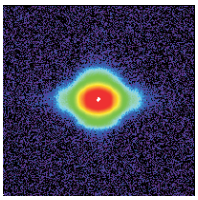
PSD calculated from above data. Spatial frequency range from 1 µm to 15 µm accessible with single-picture measurement.

Instrumentation

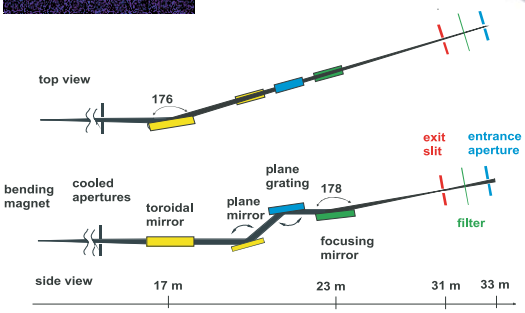
Right: PTB reflectometer with movements indicated.
Red: Sample movements
Blue: Detector movements



Beam Characteristics



Left: Beam characteristics in low straylight configuration. On the sample, the total footprint of this beam is below 1 mm horizontal and 1.2 mm vertical.

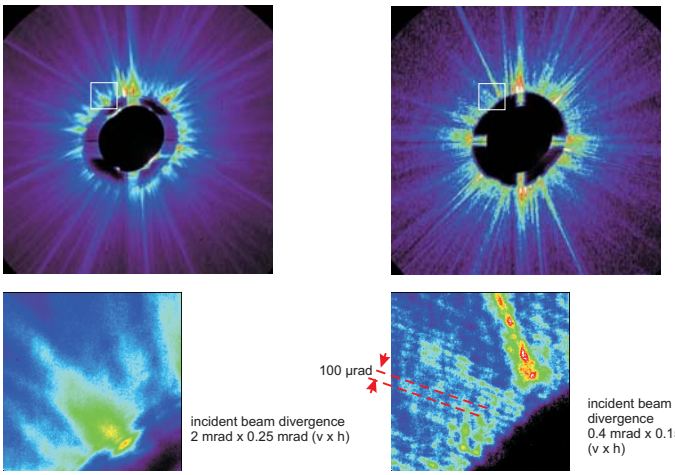


Beamline

Left: Graphics showing the setup of the PTB soft X-ray beamline at BESSY II. Optical elements and apertures are indicated.

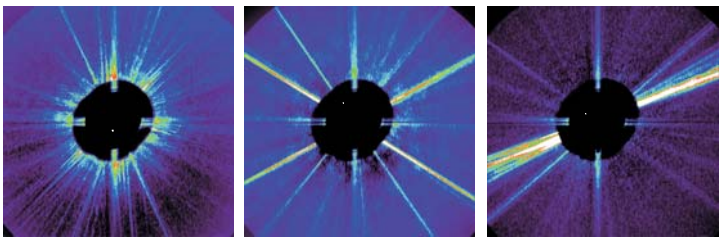
Measurement with highly collimated radiation

Measurements using a highly collimated beam reveal quasi-periodic features in the scattered light.



Diffuse scatter measured at fixed position on the mirror with different collimation of the incident radiation.
The quasi periodic structures correspond to a spatial frequency of 150 µm.

Local variations of surface topology



Measurement of scatter with highly collimated beam (0.4 mrad x 0.15 mrad).

Shown are measurements at 3 positions on the mirrorsample with the footprint of the beam moved 1 mm from one position to the next.
There are significant differences regarding scratches from polishing which lead to radial scatter lines as well as surface modulations in the µm range which lead to speckle.
The exponential decrease of the radial scatter intensity (as discussed on the left side of the poster) was subtracted from the data to better show the speckle.

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