Light scattering measurement with 157 nm techniques

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As a result of lithography systems moving to ever shorter wavelengths, industry and research are facing drastically increasing requirements for low-scatter optics in the DUV/VUV spectral region. Hence, appropriate methods for scattering measurements at the wavelengths 193 nm and 157 nm are necessary, which meet the industrial needs.

In earlier reports, we reported on total scattering (TS) measurements of optical coatings and substrates in the visible, IR and UV extending to 193 nm with a set-up operating in air /1,2/. In this report, a new scattering instrumentation for use at 157 nm (as well as 193 nm) is presented.

The design and construction of the equipment for measurements at 157 nm was driven by the following demands:

- Measurements must be performed either in vacuum or dry nitrogen to avoid absorption of VUV light by ambient oxygen and water vapor.
- Both operation in vacuum and nitrogen shall be possible, as comparison of results obtained under different conditions is desirable.
- Vacuum better than 1 x 10^{-4} mbar as well as high purity nitrogen are required.
- Time for sample change in the measurement chamber shall not exceed several minutes.
- Easy 2D mapping of sample surfaces.
- Easy change from backward to forward scattering modus in the chamber.

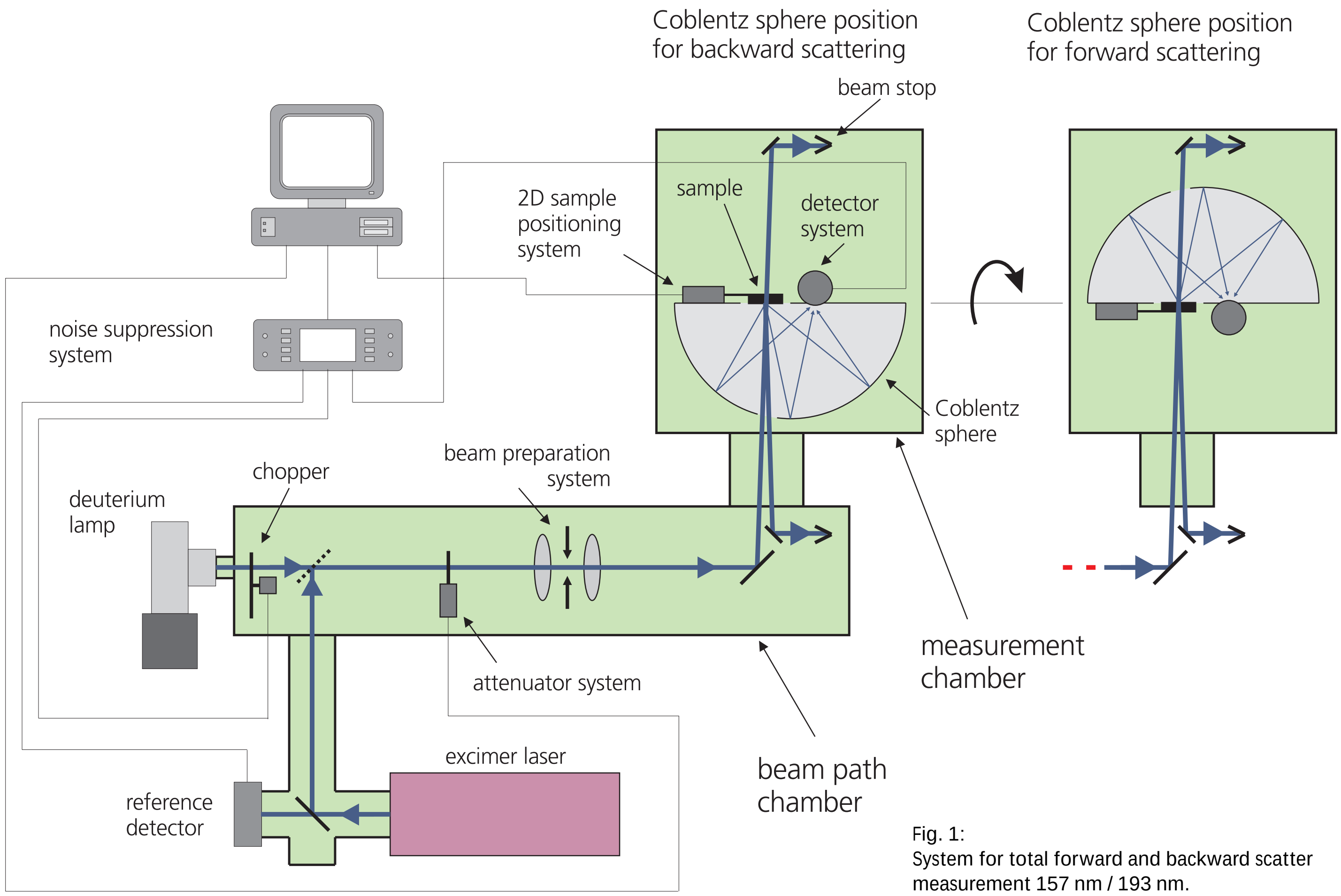

Fig. 1:
System for total forward and backward scatter measurement 157 nm / 193 nm.

– Both excimer laser and deuterium lamp as alternative radiation sources.
– High sensitivity.
– Measurement procedure shall follow the instructions of ISO/DIS 13696 as far as possible.

Furthermore,
– VUV-set-up shall be suitable for 193 nm measurements as well.
– The equipment (beam path, detection system etc.) shall also enable transmission, reflectance and lifetime experiments.

According to these requirements, we built the instrumentation schematically shown in Fig. 1. The well proven principles of the arrangement described in /1/ were kept similar wherever this was possible. Main components of the new set-up are:

– Coblentz sphere designed for scattering angular range from 2° to 85° in the backward and forward directions.
– Two vacuum chambers (steel with special surface treatment, see picture of Fig. 2): measurement chamber containing the Coblentz sphere with backward/forward positioning system, sample positioning unit, detector unit; beam preparation chamber containing optics and beam attenuator.
– Detector: photomultiplier (R1220, Hamamatsu).
– Two light sources: 30 W deuterium lamp (L7293, Hamamatsu), excimer laser (LPF 220i, Lambda Physik) with pulse energies > 25 mJ at 157 nm and > 275 mJ at 193 nm.
– Two different systems of noise suppression: lock-in-amplifier when using deuterium lamp, pulse integrating system for excimer laser operation.

Figs. 2 and 3 display pictures of the entire set-up and the Coblentz sphere in forward scatter position, respectively.

The system was successfully tested and first measurements were carried out. Even though optimization of the set-up has just started, high sensitivity has been accomplished: scatter levels as low as 1 ppm and < 10 ppm in the forward and backward directions, respectively. Change from forward to backward modus takes only 10 s. Sample change is accomplished within 6 minutes time.

Up to now, there is no established calibration procedure nor standard available for 157 nm. Our future studies will address this problem and search for new solutions. As a preliminary attempt to "calibrate" the measured data, we used as a 100% signal the incident beam directed into the Coblentz sphere, which is then reflected on the detector.

In the following, first results of measurements are presented. Both the D_2 lamp and the excimer laser were used as radiation sources. Figs. 4 and 5 refer to experiments with the D_2 lamp, the other measurements were performed with the excimer laser.

Fig. 4 shows 1D scans of back-scattered light from multilayer fluoride mirrors. One mirror was measured after deposition, the other one after aging effects had caused degradation. In Fig. 5, the results of backward and forward scatter measurements on ground CaF_2 are given. These samples are used as diffuser discs in front of the detector in the 157 nm arrangements. Fig. 6 compares backscatter measurements on HR fluoride mirrors from different suppliers. Fig. 7 provides the TS curves of differently polished CaF_2 substrates together with

Fig. 2:
157 nm / 193 nm TS set-up.

Fig. 3:
Coblentz sphere, position for total forward scatter measurement.

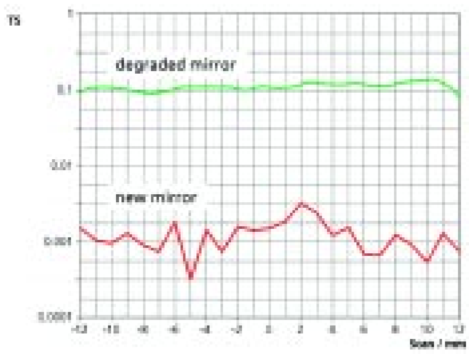

Fig. 4:
Backscatter measurements from HR multilayer (fluoride) mirrors on CaF_2 substrates, radiation source: D_2-lamp.

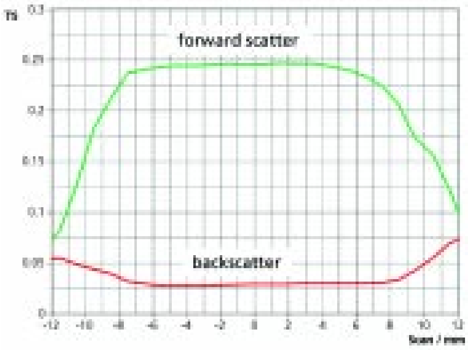

Fig. 5:
CaF_2 diffuser, total scatter measurements, radiation source: D_2-lamp.

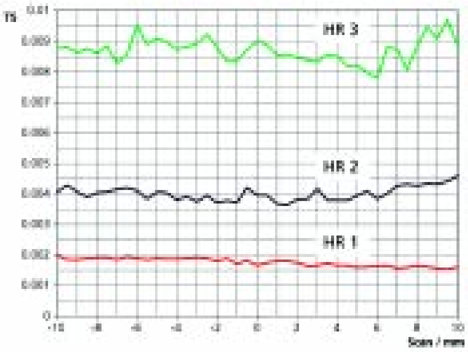

Fig. 6:
Backscatter measurements from HR multilayer (fluoride) mirrors on CaF_2 substrates, radiation source: excimer laser.

a two dimensional mapping for one sample. The forward and backward scatter of a 157 nm AR coating on CaF_2 with a corresponding two dimensional mapping is given in Fig. 8.

References

/1/ A. Duparré, G. Notni: "Multi-type surface and thin film characterization using light scattering, scanning force microscopy and white light interferometry." in: Al-Jumaily, G.A.: *Optical metrology.* SPIE Critical Revue Series. vol. CR 72, Bellingham/Wash.: SPIE 1999, pp. 213-231.

/2/ A. Duparré, S. Gliech, J. Steinert: "Roughness and scattering investigations of surfaces and thin films for DUV, VUV and EUV applications", IOF Annual Reports 1999

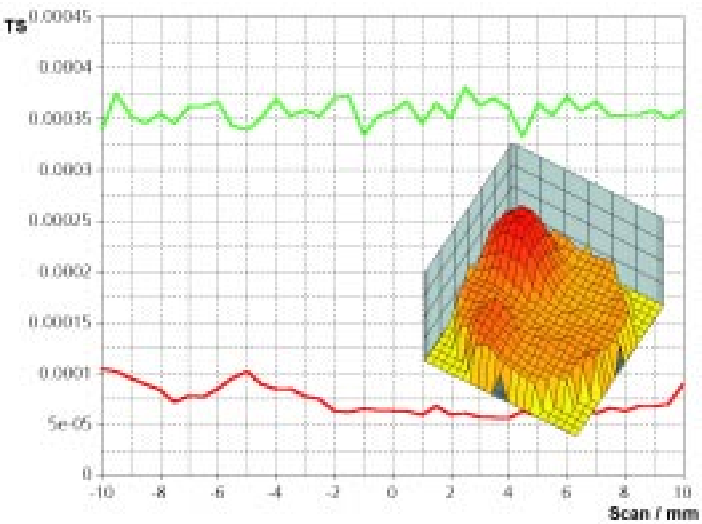

Fig. 7:
Forward scattering measurements on CaF_2 substrates with different polishing qualities, radiation source: excimer laser. Rms roughnesses of these samples calculated from measurements with mechanical profiler: low scatter sample: » 0.3 nm, high scatter sample: » 0.8 nm.

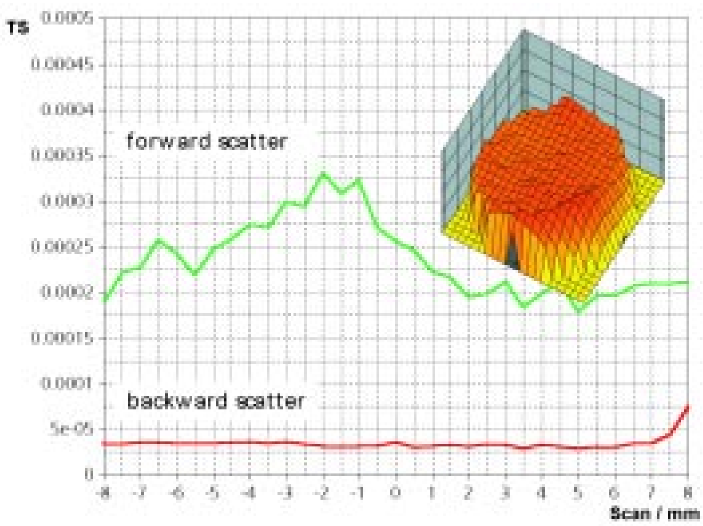

Fig. 8:
Forward and backward scattering measurements of AR coating on CaF_2, radiation source: excimer laser