Fast characterization of moving samples with nano-textured surfaces: supplementary material

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Dual Beam Cube Setup

A setup with simultaneous acquisition of the image and spectrum has also been implemented, as sketched in Fig. S1. Here a second beam splitter cube (50/50) has been introduced between the objective and the beam cube for coupling the light in. The advantage of this setup is that one does not have to switch between the camera and the spectrometer, but on the other hand the light intensity is reduced by 75 %. Otherwise this setup is also very robust to vibrations, and except for an increased dark signal, a 4-fold increase in acquisition can be acceptable.

dashed area are the modification to a conventional microscope. The extra components include a second 50/50 beam splitter (BS), lenses for coupling the light into a fiber, and a spectrometer. The CCD camera is used for finding the area of interest and to secure the sample is in focus. Acquisition of spectra using the fiber setup is very robust and therefore this microscope is also suitable for industrial implementation. The drawback of including a second BS in the setup is that the light intensity is reduced by a factor of 4 and that more stray light is present, leading to a larger dark signal that one has to correct for.

Figure S1. Sketch of the experimental setup for simultaneous data acquisition of the spectrum and the image. The components within the

Thin Film Measurements

Thin film transfer standards are used for validation of the system. Si(100) substrates with a SiO₂ layer are used for the validation. The thickness of the SiO₂ was measured using traceable spectroscopic ellipsometry. An example of experimental data obtained with the dual-beam cube microscope is shown in Fig. S2.

Figure S2. Scatterometry measurements on a thin film transfer standard. (A) Experimental data and best fit for a transfer standard with a nominal SiO_2 layer thickness of (1003.0 ± 5.1) nm. Several oscillations in the wavelength-dependent scattering intensities give a low uncertainty on the fitting parameter. (B) The χ^2 value as a function of the fitting parameter, the thickness of the SiO_2 layer. The global minimum at 1002 nm has a much lower χ^2 value than its neighbors, thus indicating a small confidence interval on the fit. The relation $\Delta\chi^2 < 4$ is fulfilled for a thickness of ± 2 nm. Hence the thickness of the SiO_2 is found to (1002 ± 2) nm, where $\pm$ indicates the 95 % confidence interval of the fit.

Reference measurements

The height of the ridges is measured using a metrology AFM (NX20, Park Systems) in tapping mode with PointProbe Plus Non-Contact AFM probes (Nanosensors), with a specified apex radius < 10 nm. The AFM has a z-flexure stage equipped with strain gauge distance sensors and an xy-stage equipped with optical distance sensors. The microscope was calibrated using a step height standard as described in Refs. [1,2].

Figure S3. Atomic force microscopy image for traceable measurement of the height of a grating.

An area of $10 \mu\text{m} \times 10 \mu\text{m}$ of the 1D gratings is imaged with the fast scan axis perpendicular to the ridges as shown in Fig. S3. The images are analyzed using the step height module in SPIP (ver. 6.2.5, Image Metrology) and following ISO5436 standard for measuring step heights. A profile for each line scan is extracted and the height is the mean of all ridges in all scan lines, which typically is a few hundred measured ridges. Parameters for height estimation area are in accordance with the ISO standard set to middle length = 33 %, side length = 66 %, and edge distance = 33 %. For the grating with a 800 nm pitch the mean step height is found to $h = 189.1$ nm with an expanded uncertainty ($k=2$) equivalent to a confidence interval of around 95% of $U(h)=1.3$ nm. Scanning electron microscope (SEM) images are obtained to find the filling factor of the 1D grating. The filling factor is defined as the ratio between the width of the structures and the pitch of the grating, that is, $FF = w_{\text{ridge}}/p$. This approach is only valid for structures with vertical sidewalls. In our case the sidewalls are very close to vertical and hence we can use this approach. Typical SEM images are shown in Fig. S4.

Figure S4. Scanning electron microscopy images of the 1D silicon gratings with a nominal pitch of (A) 800 nm and (B) 1400 nm.

Scatterometer data

Periodic gratings with pitches ranging from 700 nm to 1400 nm have been measured with the scatterometer. For pitches in the lower range more oscillations in the diffraction efficiencies with respect to wavelength are found. The fitting procedure is more robust when fitting to such oscillations than to the monotone curves obtained at the large pitches. Hence the confidence limits for the low pitches are lower than for the large pitches. Experimental data for the gratings with 700 nm and 1200 nm pitches are shown in Figs. S5 and S6.

Figure S5. 1D grating in Si(100) with a pitch of 700 nm. Parameters for the best fit are: height = (188 ± 2) nm, FF = 0.4575 ± 0.005 , and

sidewall angle = 88.0 ± 2.0 . Here $\pm$ indicates the 95% confidence interval of the fit.

Figure S6. 1D grating in Si(100) with a pitch of 1200 nm. Parameters for the best fit are: height = (191 ± 2) nm, FF = 0.4875 ± 0.013 , and sidewall angle = 84.0 ± 6.0 . Here $\pm$ indicates the 95% confidence interval of the fit.

Rotation of sample

For TE measurements the polarization of the incoming light should be aligned with the grating direction. The sample is rotated, θ_{sample} , away from alignment to investigate the robustness of the setup, as shown in Fig. S7. It is seen that for rotations less than 60° in each direction the 95 % confidence level (defined as $\Delta\chi^2 < 4$) is not exceeded. By relating to the estimated values of the confidence levels, we can correlate that a rotation less than 60° gives rise to an uncertainty of less than 2 nm in the height, 0.005 for the filling factor, and 2σ for the sidewall angle.

Figure S7. Rotational misalignment of the sample. The solid black line is a second-order fit as a guide to the eye. The red horizontal line indicates the $\Delta\chi^2 = 4$ limit.

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