Realization of depth reference samples with surfaces amplitudes between 0.1 nm and 5 nm

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Abstract. A new approach for the realization of depth reference samples is presented. By a combination of photolithography, reactive ion beam etching, surface planarization with photoresists and a subsequent coating with non-transparent materials, defined sinusoidal surface profiles are generated which can be used as depth references for the comparison and calibration of different surface profile measurements. The smallest realized surface amplitudes are in the range of less than 0.1 nm.

1 Motivation

In the high-precision production of optical surfaces, roughness values in the range of 0.15 nm and below are now required. Such values are achieved by sophisticated polishing techniques, e. g. ion beam polishing. In addition, the fabrication of precision surface gratings with height modulation ranging from some nanometers down to sub-nanometer becomes more and more important, e. g. for diffraction gratings as used in vacuum–ultraviolet and soft x-ray spectral range.

In this context, the accurate and reliable measurement of corresponding surface profiles is of essential importance. Usually a high number of reference samples are commercially available which are used for the calibration/evaluation of surface profiling techniques as Scanning Force Microscopy (AFM) or White Light Interferometry (WLI). However, depth or roughness reference samples used for calibration of these methods have mostly relative high surface amplitude of some tens or some hundreds of nanometers. Ideally, the vertical dimensions of the features of the calibration samples should be in the same order of magnitude as the typically surface features to be measured.

In an earlier work [1] we could already show that reference samples with amplitudes down to 0.1 nm can be produced by the combination of lithography and reactive ion beam etching (RIBE). However, the process was relatively complex and time consuming, because a multi-layer system had to be patterned. Here a simpler process is proposed which allows to obtain sinusoidal surface profiles with low amplitude heights.

2 Experimental realization of depth reference samples

Figure 1 illustrates the process flow schematically. In the first part of the process, a lithographically defined resist mask is transferred by RIBE into a Si wafer, where the depth of the generated binary grating is adjusted by the etching time.

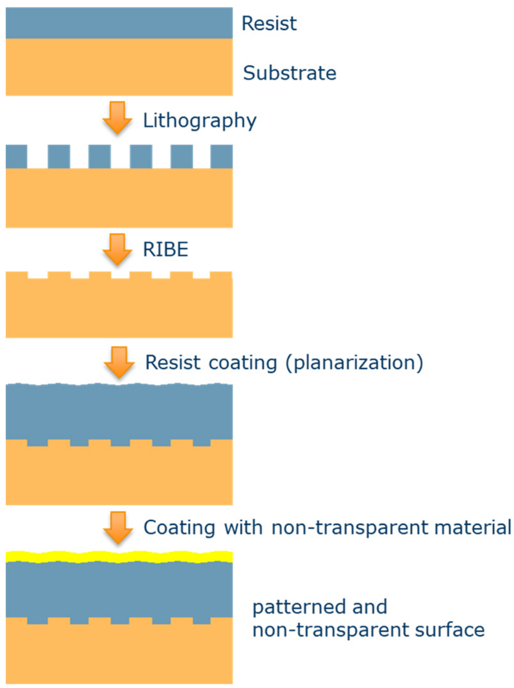

Fig. 1. Schematic process flow for the realization of the sinusoidal surface profiles.

In a second step a resist layer is applied with spin coating again which leads to a planarization of the surface and converts the previously binary profile into a sinusoidal profile. The surface planarization is caused by tension-driven flow of the viscous resist film [2]. The degree of planarization (reduction of surface amplitude) is determined both by the properties of the photoresist (viscosity, film thickness) and the properties of the initial Si surface profile (period, grating depth). In the final step, the wafer is coated with a thin layer (30 – 50 nm) of a non-

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transparent material (Au, other metals, Si, …). Here, magnetron sputtering was used which allows a conformal coating without changing the surface profile.

The Si wafers used had a diameter of 4 inches with regularly arranged fields of different periods and a lateral dimension of 15 mm x 15 mm being applied to the wafer. Other layouts are also possible.

3 Surface profile measurements using AFM and WLI

Figure 2 show AFM measurements of surface gratings with 4 µm period in (a) the Si surface after RIBE, (b) the resist coated planarized surface and (c) after final Au coating.

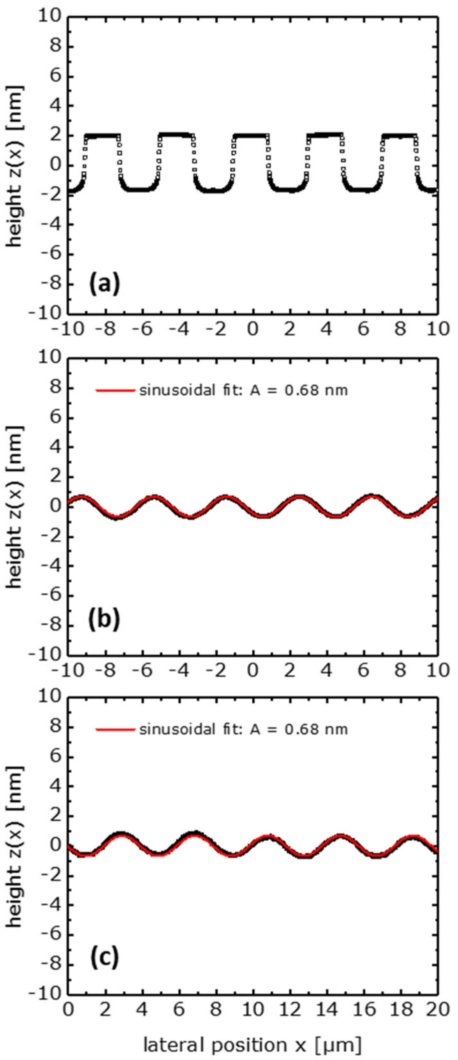

Fig. 2. AFM measurements of surface profiles with 4 µm period for (a) the initially binary grating in Si, (b) the sinusoidal profile after resist planarization and the final profile (c) after Au coating. The open symbols correspond to the measured AFM profile averaged over 256 scan lines, the red line is a sinusoidal fit to the measured profile.

The surface profile is not affected by the Au coating and the amplitude remains unchanged as indicated by the values of surface amplitudes (A = 0.68 nm) obtained from a sinusoidal fitting to the measured data.

Results for the WLI (50 x objective) measurement on a grating with 2 µm period are given in figure 3. The evaluation of the measurements results in a profile amplitude of (89.1 ± 4.4) pm. As described above, fields with a size of 15 mm x 15 mm were produced on the Si wafer. Measurements at different locations within a field show a typical standard deviation for the surface amplitudes of typically 5 pm, independent of the respective profile height. Nearly the same value was obtained from the corresponding AFM measurements.

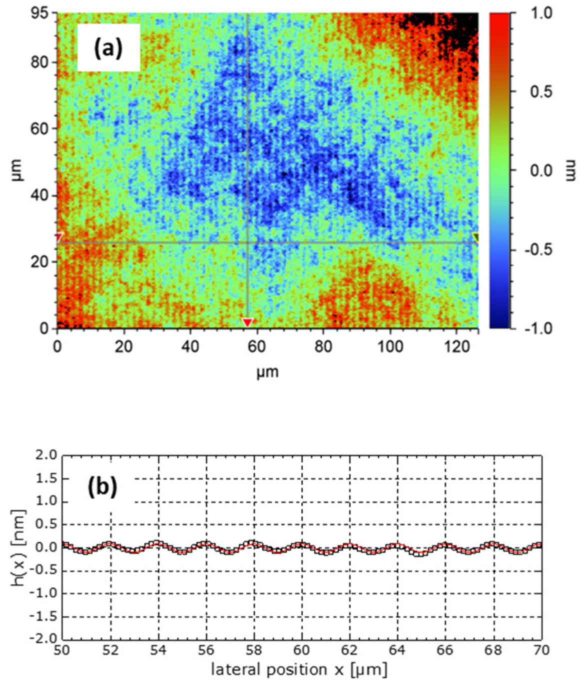

Fig. 3. WLI (50 x objective) measurements of Au coated surface profiles with 2 µm period: (a) measured surface topography, (b) averaged profile (open symbols), and sinusoidal fit to the measured profile (red line).

In conclusion a new approach for the realization of depth reference samples was presented. The adjustable profile amplitudes cover the range from approx. 5 nm to less than 0.1 nm. First evaluation measurements using AFM and WLI were presented.

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References

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