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Zuerst erschienen in:

DGaO-Proceedings. - Erlangen-Nürnberg: Dt. Gesellschaft für angewandte Optik, ISSN 1614-8436. - Bd. 113.2012, A3, insg. 2 S.

URN: urn:nbn:de:0287-2012-A003-6

Imaging gratings with modulated blaze - realized by a combination of holography and reactive ion beam etching

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Blazed gratings are in general the best choice for achieving the maximal diffraction efficiencies in a moderate wide wavelength band. However, a number of applications such as typical spectrometer systems need a broader spectral range. Here the drop of diffraction efficiency for the employed order towards the edges of the addressed spectrum limits the dynamics of the spectral sensor system. Thus we present a systematic approach based on a combination of interference lithography and ion beam etching. It provides a tuneable spectral response curve even for imaging gratings by mixing the characteristics of different blazed angles without influencing the systems spectral resolution.

1 Motivation

Aim of this work is an enhanced spectral characteristic for a blazed imaging grating of a universal compact spectrometer working from the DUV range up to the NIR region. In order to achieve the correct hologram function in combination with a blazed grating structure a recording setup as sketched in Fig 1 is employed. The two interfering laser beams are propagating from both sides of the spherical glass substrate [1], [2]. The resulting grating shows a slight local variation of the line densities and has a period of 1.9µm in the center.

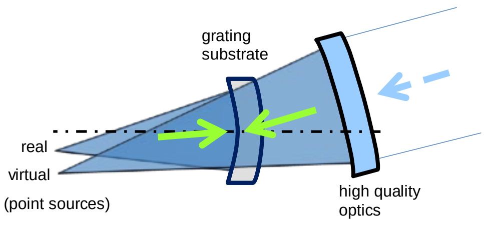

Fig. 1 *Recording scheme for imaging blazed gratings*

Due to the physical boundary conditions the resist profile shows a constant depth of about 100nm over the whole former interference region. To adapt these holographic blazed gratings for applications in a certain wavelength range an additional reactive ion beam etching (RIBE) step offers a way for a vertical scaling while transferring the grating structure into the glass material. Depending on the parameters of this etching process, a transfer ratio below 1 up to about 10 is possible.

2 Technological realization

This etching process offers another degree of freedom for the resulting diffraction grating. By splitting the transfer into two steps and covering the sample with a thin metal mask very close and accurate positioned above the resist pattern, certain regions can be etched with different transfer ratio and the final element shows novel interesting properties. In Fig 2 the succession of a two step ion etching process is illustrated in principle.

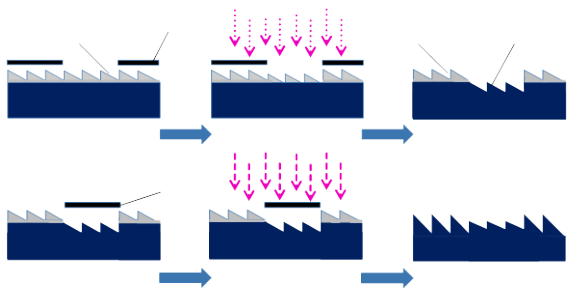

Fig. 2 *Modified transfer process of the resist pattern by integration of complementary structured masks*

In order to prevent the modified spectrometer from sensitivity to an inhomogeneous illumination of its pupil plane – here this plane corresponds to the grating surface itself - the different blazed grating areas have to be distributed in a suitable pattern. Therefore a slit array like mask is used. Fig. 3 shows the mechanical parts as well as the manufactured and investigated master grating with a usable diameter of 25mm. The covering mask was designed to provide a gap to the substrate surface of less than 0.1mm. The overlay error is about 10micron. By rotating this slit mask by an angle of 180degrees the former covered areas may then exposed to the ion beam. This way, one single mask serves for complementary covered grating areas at both etching steps.

Fig. 3 *Etching mask (left), substrate holder (middle) and Al-coated master grating with two different blazed regions arranged in a stripe pattern (right)*

3 Properties of the modulated blazed grating

Fig. 4 shows the spectral efficiency characteristics of the first demonstration unit's blaze structures. These curves are based on calculations using the real profiles captured by AFM measurements.

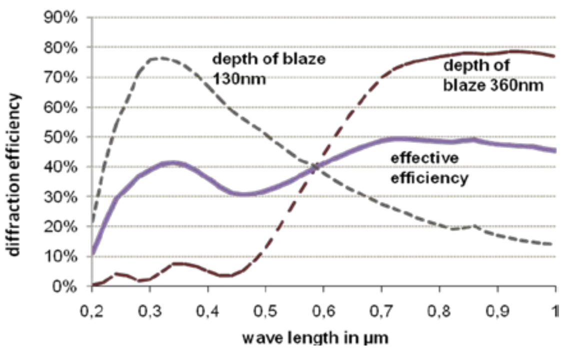

Fig. 4 *Spectral efficiencies (unpolarized) for the -1th diffraction order for two different depths of the holographically generated blazed profile (dashed lines) and the resulting curve for the imaging grating (solid line)*

The depths of the two blazed regions that are based on the one single resist grating are 130nm and 360nm. Thus 50 percent of the optical active area shows a behavior like a DUV-grating with a peak due to the application setup slightly above 300nm. The remaining grating portion corresponds to a VIS/NIR-grating with a broader peak between wavelengths of 800nm and 1µm. Therefore, if integrated in the spectrometer this grating would provide an overall efficiency as indicated by the solid line that corresponds to the mean value of the two initial curves. It shows clearly a more balanced efficiency over the spectral region of interest. Further, this curve shows two spectral separated peaks which are not achieved by known alternative profiles like that of binary or sinusoidal gratings.

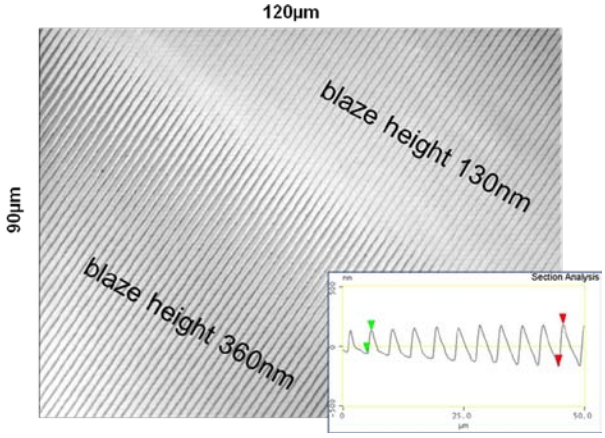

Fig. 5 *Microscope image of a transition region between the two different blaze depths, the lower right part shows a tilted AFM scan between the middle of the transition range towards the deeper blazed region*

Fig. 5 shows a microscope image of a transition region between the two different blazed areas. Remarkable is the very clean and continuous transition of about 20µm with no unstructured locations and no artifacts. Thus we expect no relevant increase of scattered light.

4 Conclusion and outlook

Based on the two-step-RIBE-transfer process a blazed imaging grating with optical properties equivalent to a conventional holographic type and an 'artificial' spectral characteristic was achieved. The example has still potential for further improvement. In general due to the spectral sensitivity of typical sensor elements the ratio between the two grating parameters may be better adapted if the DUV-portion is increased. First results show the potential for further refinement of the etching mask structure too to provide even more robustness against inhomogeneous angular intensity distributions of the investigated light signal.

Acknowledgements

We would like to thank the TMWAT for the partial funding of this work - project 2008 FE 9147.

References

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