Deliverable 4.2: Report on first fabrication of pulse compression grating with 98% diffraction efficiency on large area, rectangular substrate material

Dissemination Level: Confidential (CO)

Owner

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Context

Author(s):	Michael Moeller + Thorsten Wahlbrink
Work Package:	WP4
Task:	T4.2 Development of an optimization of a lithography process for the fabrication of pulse compression gratings T4.3 Development and optimization of an etching process for the fabrication of optical components

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Declaration: Any work or result described therein is genuinely a result of the Hiperdias project. Any other source will be properly referenced where and when relevant

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Version History

Version	Summary of Change	Written By	Approver	Date
0.1	First draft	Michael Moeller + Thorsten Wahlbrink	Thorsten Wahlbrink	20.12.2016
0.2	Correction	Michael Moeller	Thorsten Wahlbrink	11.01.2017
0.3	Final Draft	Michael Moeller and Thorsten Wahlbrink	Marwan Abdou-Ahmed	13.01.2017
1.0	First Issue	Michael Moeller	Marwan Abdou-Ahmed	20.01.2017

Scope

This deliverable (D4.2) summarizes the results of the fabrication process development and the optical characterization of the first pulse compression grating generation in Hiperdias. Large area, rectangular shaped fused silica substrate material with Ta_2O_5 dielectric multilayer stack on top has been used. Based on a design provided by IFSW, first compression gratings have been successfully fabricated by AMO, using Laser Interference Lithography (LIL) and Reactive ion etching (RIE). The optical characterization revealed diffraction efficiencies larger than 99%. These promising results have been achieved by the work done in Task 4.2 and Task 4.3 of WP4.

Process development and optimization

Within Hiperdias compression gratings based on leaky-mode grating mirrors are investigated. The IFSW calculated the geometrical dimensions of these gratings (Deliverable 4.1: Report on simulation of pulse compression gratings with diffraction efficiency >=99% over large spectral bandwidth (5-10 nm) around 1030 nm). Based on this design targets AMO develops and optimizes manufacturing processes for the fabrication of the gratings.

For the first generation of compression gratings, 75mm x 50mm large fused silica substrates with SiO_2/Ta_2O_5 multilayer stack have been used. The main fabrications modules are the definition of the grating structures by LIL and the subsequent transfer of the grating structure into the underlying Ta_2O_5 layer.

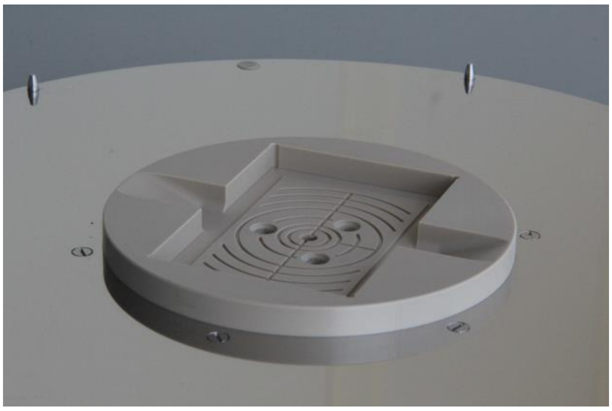
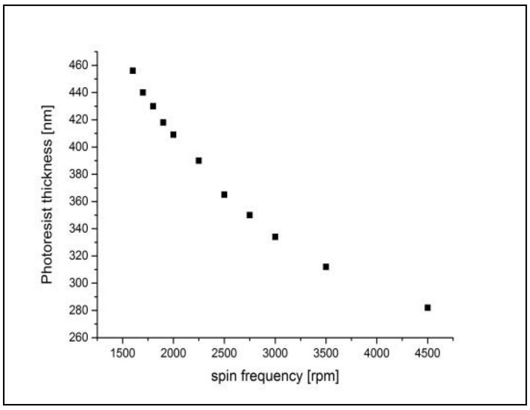
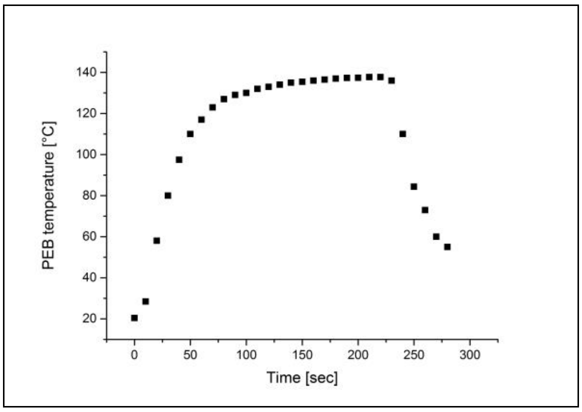


Figure 1: Chuck system

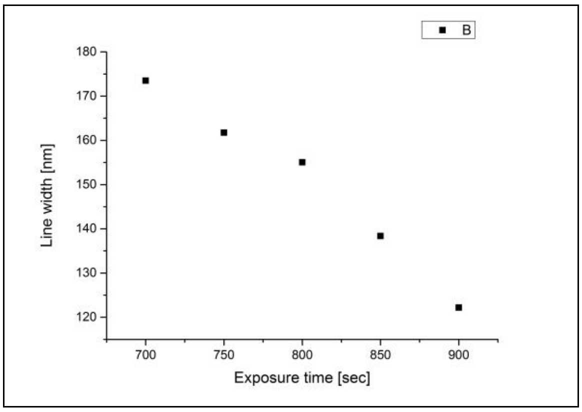


Graph 1: Spin curve photoresist

The spin coating system RCD8 was modified with a new chuck system (Figure 1), that allows us to handle a new substrate format. The photoresist material was diluted with a solvent especially for the process development and optimization, and characterized with a spin curve shown in Graph 1.
We gained optimized process parameter for the precise control of line width, respectively duty cycle by performing exposure dose variations in combination with adapted post exposure bake (PEB) temperatures and times.

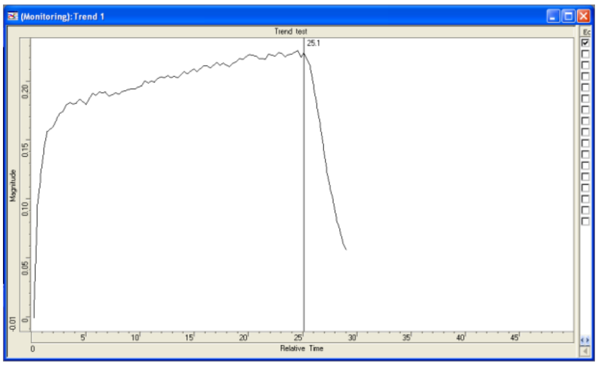


Graph 2: PEB temperature



Graph 3: Line width versus exposure time

It can be clearly seen in Graph 2, the PEB temperature rises up very slowly due to the weak heat conduction of fused silica and the large material thickness. For this reason the bake time was enlarged from 90 seconds to now 240 seconds. The baking temperature and time are very important parameter, because both affect the chemical amplified of the photoresist and therefore size of the process window. Graph 3 shows the behavior between exposure time and line width for the optimized PEB parameter.



Graph 4: Endpoint system

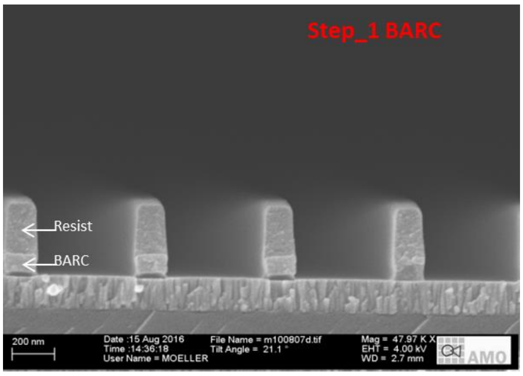


Figure 2: etched BARC

A two layer system, comprising a BARC (Bottom AntiReflection Coating) and the DUV positive photoresist is used as etch mask for the pattern transfer into the dielectric top layer. So far an endpoint detection system based on plasma spectroscopy was evaluated for the BARC etching procedure. Graph 4 shows the endpoint at approximately 25 seconds etching time, when the intensity of the specific emission line drops significantly. The sem photography proves the successful etching result.

A fluorine-based reactive ion etching is used to etch the underlying Ta_2O_5 layer, resulting in 200 nm deep grating structures. Following the etching step several wet chemical cleaning routines have been used to remove residual resist remaining after as well as passivation layers formed during the etching.

Results

The fabrication of first generation gratings has been finalized. An analysis of the geometrical dimensions including duty cycle and etching depth has been done on a large number of samples. Figure 3 shows the cross-section of etched pattern with 206 nm etching depth. Low surface roughness of the etched features is clearly observed.

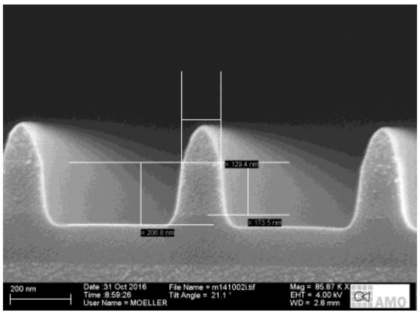


Figure 3: Section test grating

Particular attention is paid in our analysis to the geometrical grating parameter. The design target was 0,24 for the duty cycle and 210nm for the etch depth in order to achieve over 99% diffraction efficiency. On the left hand side of Figure 4 a plot of the etch depth is shown measured on 9 points on the grating surface (grating No. M081104). The etch depth varies slightly from 198nm to 209nm. On the right side the duty-cycle is shown, varying from 0.25 to 0.27. Due to the large variation of especially the duty cycle not all characterized points are within the target above.

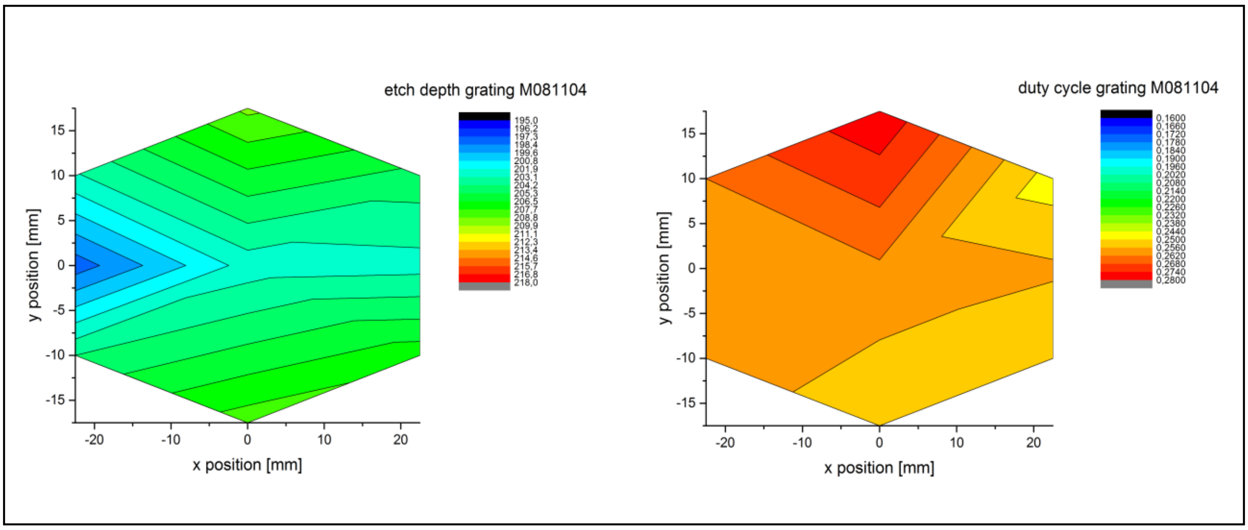


Figure 4: 2-D plot of etch depth and duty-cycle inspection

An analysis of the geometric grating parameter was carried out for 10 gratings at the center position of the substrate surface. The results are summarized in Table 1 below.

grating No.	duty cycle	etch depth [nm]
M081103	0,200	208,6
M081104	0,261	204,2
M081105	0,265	204,7
M081106	0,261	206,4
M091101	0,206	204,4
M091102	0,246	203,7
M091103	0,265	208,3
M091104	0,254	207,1
M091105	0,254	194,7
M091106	0,240	213,9

Table 1: Geometric grating parameter

It can be seen from Table 1, large duty cycle deviations are present for grating No. M081103 and No. M091101. The etch depth varies between 213,9nm and 203,7nm for nine gratings. The reproducibility of the geometrical grating parameter will be further investigated during the project.

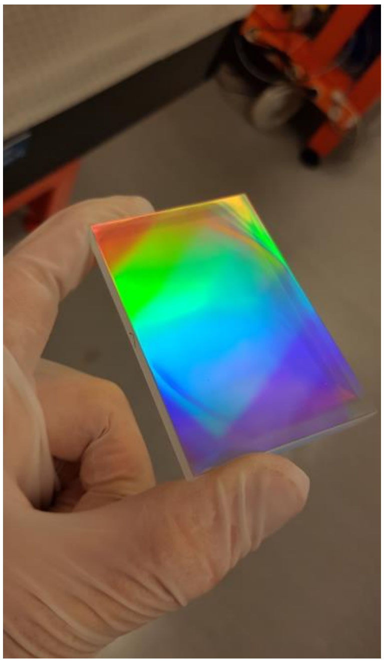


Figure 5: Photo of one of the fabricated gratings

The optical characterization of the pulse compression gratings was carried out by the IFSW. Figure 6 shows the typical measured diffraction efficiency versus wavelength (shown only for 2 samples). The other samples show similar behavior.

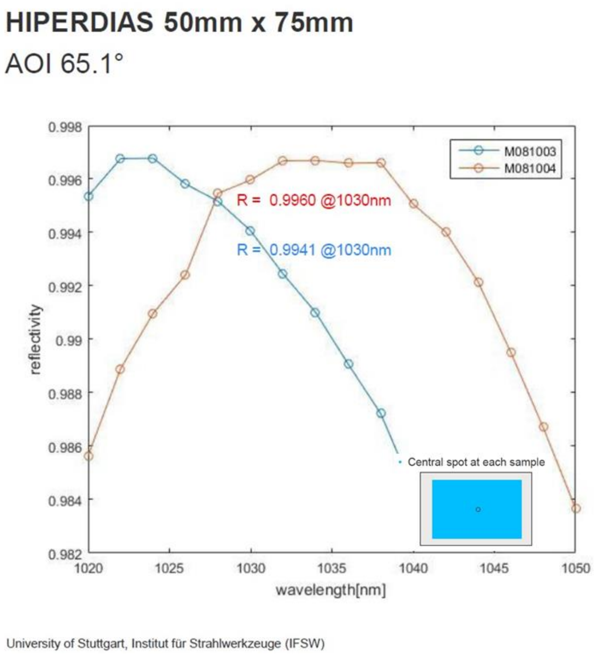


Figure 6: Measured diffraction efficiency versus wavelength for sample M081104

Both gratings (labeled as: M081103 and M081104) show a spectral reflectivity larger than 99% at a central wavelength of 1030nm. The grating with label M081104 even shows a reflectivity larger than 99% at 1030nm with a spectral bandwidth of 10nm. The measurements were carried out at the center position of the substrate. Although the maximum of the reflection curve is shifted by 5 nm to longer wavelength, these results are very promising for the further development of the grating compressors aimed in HIPERDIAS.

The following work will be focused on the analysis of the shift and subsequent optimization of a second grating series with minimized shift in the reflection curve.