Spin-coating of photoresist on convex lens substrates

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Motivated by the requirements of the fabrication of diffractive phase structures on convex lens substrates, we evaluated the abilities of spin-coating to realize homogeneous photoresist layers also on appropriate curved surfaces. For the observation of the thickness variation at numerous 3D-positions we realized an automated measurement station based on an existing tool for flat surfaces.

1 Motivation

The realization of diffractive structures on standard convex lens substrates (Fig. 1) provides an additional degree of freedom for optical designs. This is important to find even more compact and powerful optical solutions for a wide field of applications.

For the fabrication of diffractive phase structures via direct laser writing (for example with a CLWS300), a homogeneous coating of photoresist is required. On flat surfaces this can easily be achieved by spin-coating: a small quantity of photoresist is distributed evenly over the surface by fast rotation. In this publication we report our first coating results on curved substrates.

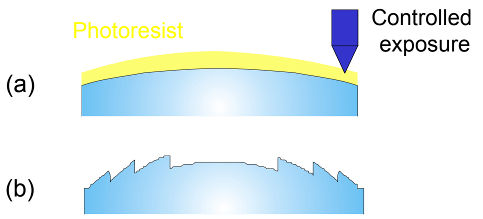

Fig. 1 *(a) Coating of photoresist on curved lens substrate before the computer controlled exposure and demonstration of the desired diffractive structures (b).*

2 Automated Metrology

For a point measurement of the coating thickness on flat substrates, a well-known method is to determine the spectral reflectivity and compare it with results of a model, in which the thickness is a fit parameter.

To evaluate the average thickness and homogeneity on curved surfaces, the measurement head of our existing tool (Sentech FTP500) must be moved to different positions, but keep its orientation normal to the surface to collect sufficient light. Therefore we installed two computer controlled axes (Fig. 2, Fig. 3): The first one rotates the measurement head around the center of curvature of the lens to keep the working distance and orientation. The second axis turns the lens. The control of these two angles allows a definition of arbitrary measurement positions over the curved lens.

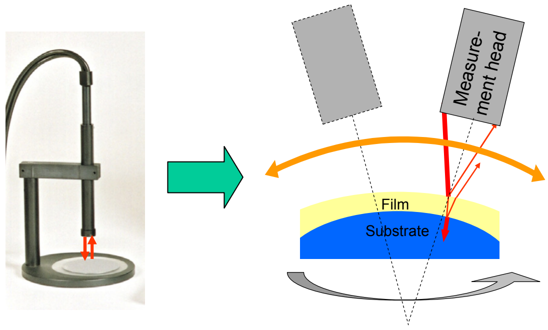

Fig. 2 *Measurement head of a reflectometer from Sentech (FTP500) and motorization setup with two axes to set different positions and keep the measurement conditions.*

The realization of the motorized setup is shown in Fig. 3. The vertical position of the lens can be adjusted to provide a rotation around the center of curvature for different lens radii.

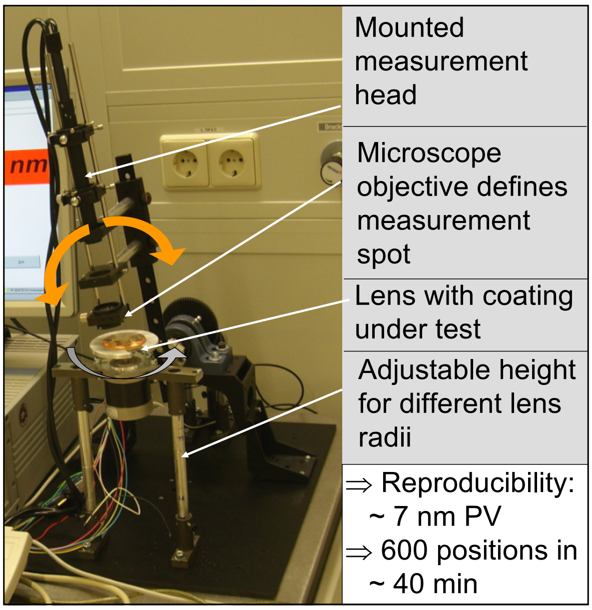

Fig. 3 *Realization of the measurement station.*

The reproducibility of the measurement station was tested on a coated 2” lens with 28° inclination angle at the edge (Fig. 4): The peak-to-valley (PV) of the difference, which shows the maximum range of change, is only 7 nm for a coating thickness of about 3.3 µm.

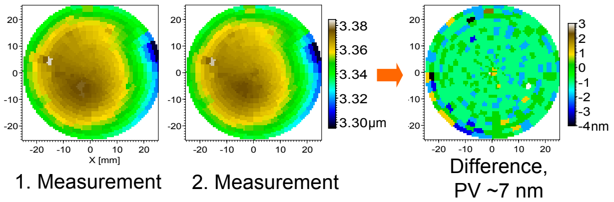

***Fig. 4** Repeated measurements of the same coated lens to demonstrate the reproducibility of the measurement station.*

3 Coating results and analyis

Our main focus was the investigation of coatings on a 2" lens with a maximum inclination angle of 28°. The first results of a systematic combination run of different photoresists and final rotation speeds are shown in Fig. 5. Besides thickness, which is color-coded, also the overall PV of each experiment is mentioned. With about 1 ml of photoresist and the shown parameters, the complete surfaces could successfully be coated. The average thickness increased with higher viscosity and smaller rotation speed (Fig. 5, Fig. 6), which is similar to results on flat surfaces.

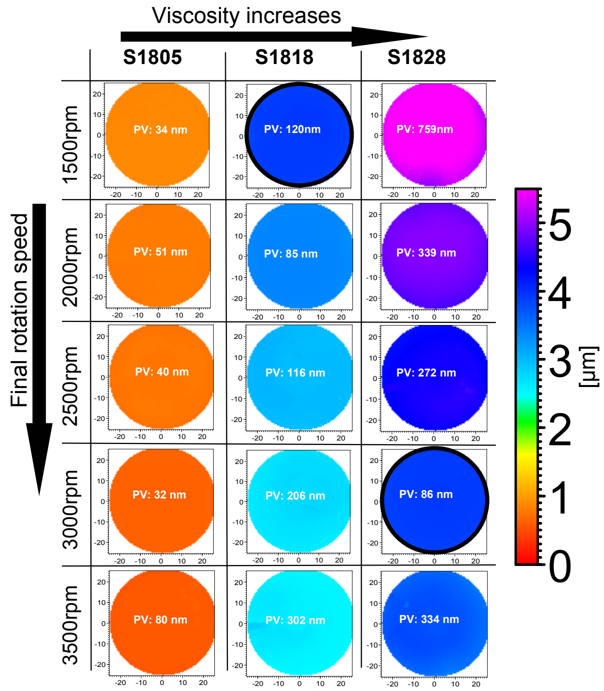

***Fig. 5** Results of a systematic series with different photoresist viscosities and final rotation speeds.*

The homogeneity of most of the coatings was good over the complete surface in spite of the curvature. The analysis of angular resolved homogeneity showed, that the thickness variation increases towards the steeper slope at the edge of the lens (Fig. 7).

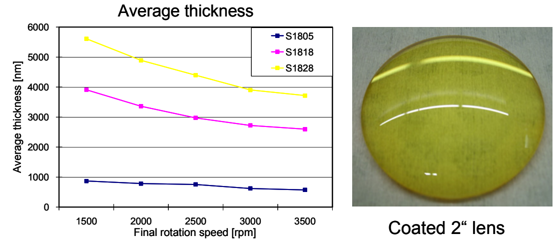

***Fig. 6** Average thickness of the photoresist coatings shown in Fig. 5; image of a lens with coated surface.*

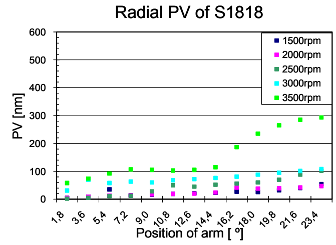

***Fig. 7** Radial PV of the coatings realized in the first series with the photoresist S1818.*

For the realization of a desired average thickness, different combinations of viscosity and rotation speed could be applied. Within our first measurements two possibilities for a coating of about 4 µm were included (Fig. 8). The lower viscosity produced a better rotation symmetry close to the middle of the lens, but at the edge the thickness is considerably decreased at one location. Nevertheless the overall homogeneity of both coatings is better than 5% of the average thickness, which is a good result.

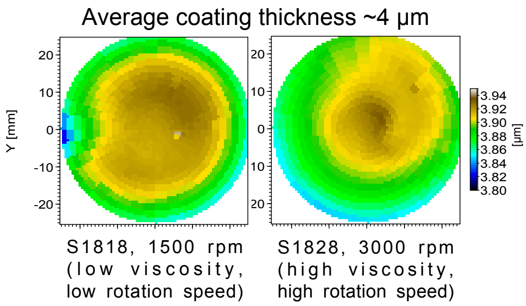

***Fig. 8** Visualisation of the resulting photoresist distributions for different parameter sets producing a similar average thickness of about 4 µm.*

4 Summary

With our new measurement station we demonstrated, that spin-coating with standard parameters can produce good photoresist coatings also on the convex surface of a lens in spite of a maximum inclination angle of about 28° at the edge.

5 Acknowledgements

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