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MARKERS FOR REFERENCING TOPOGRAPHY MEASUREMENT DATA OF OPTICAL SURFACES

Andreas Müller, Rostislav Mastylo, Nataliya Vorbringer-Dorozhovets, Eberhard Manske

Technische Universität Ilmenau,
PF 100565, D- 98684 Ilmenau, Germany,
andi.mueller@tu-ilmenau.de,

ABSTRACT

Topography measurements of optical systems are done with various methods, each of it using its own data grid, point of origin or even coordinate system. Fitting procedures and interpolations are implicitly needed to enable the comparisons of measurements.

In this paper we describe the development and the production of a series of marker structures for a more direct way of alignment and position reference of optical surfaces measurement data. By implementing the markers, the capabilities of 'scanning lithography' were demonstrated, using the nanopositioning and nanomeasuring machine NMM1 for providing the precise lateral and height position control of the sample, while a focused exposure laser beam was coupled and collimated into the surface scanning focus probe. After having successfully applied markers to the surface, the qualities of the shapes have been inspected.

Index Terms - markers, coordinate referencing, surface measurement data comparison

1. INTRODUCTION

Improving metrology for modern optical surface production increasingly requires the possibility to compare or even to fusion data sets resulting from several various high level surface measurement technologies for optical systems. Since each of these measurement technologies has its special capacities, its own 'tip' – surface interaction, its advantages and its disadvantages, this wide range will develop further in future. The more precisely the data comparison and a following error analysis can be done; the more exact statements about the capabilities, e.g. uncertainty, transfer function or even surface impact of the involved measurement approaches can be made. But this all is aiming for the final goal, to receive more precise and more reliable knowledge about the real surface under test.

Measurement of optical systems, like asphere or freeform surfaces is done with various methods, particularly optical and tactile, each of it using its own data grid, point of origin or even coordinate system. Therefore comparisons, if at all, are possible after using fitting procedures, interpolation and sometimes coordinate transformation to adjust the different data grids. The internal coordinate system of the measuring device usually does not provide a proper traceability for the relative point of origin of the surface under test, since with respect to nanometre range, every time the setup is changed, the position of the surface or tip is more or less unknown.

To overcome this problem, a set of markers can be applied, to add significant surface exaltations to the rather smooth topography of optical systems. By recognising and locating their positions in the measured data set, a predefined coordinate system can be reconstructed from the measurement data. By doing this, correct data comparison or data fusion of measurements stemming from various technologies can be enabled.

2. COORDINATE REFERENCING

2.1 Fitting geometrical forms

To apply coordinate referencing in the measured surface of aspheres and freeforms, fitting procedures of geometrical forms are commonly used. This fitting procedures usually involves six degrees of freedom, three translations and three rotations. In practice the forms of common objects under test provide more or less significant surface exaltations in each of the directions of the different degrees of freedom. Thus for each of these directions the results of the fit are more or less sensitive and will reach different precision. As an example, applying the form fit on a spherical surface and regarding x- and y tilt fit, just aligns the measured surface area perpendicular to the measuring axes, only centring the x- and y-position in the middle of the captured sphere fraction. That means that the prolongation of the measuring axes through the x- and y-position matches the centre of the sphere. But the captured sphere fraction can be chosen by chance. Since the spherical surface itself is arbitrary to x- and y-tilt, no real coordinate reference for the x- and y-position of the captured sphere fraction in relation to the absolute sphere surface can be gained of this procedure. For aspheres however, only the deviation from the spherical form provides an input to the x- and y-tilt fitting and thus as well to the determination of the x- and y-position of the captured surface fraction. The inclusion of bordering edges of the optical surface into the measurement may increase the precision of referencing, but also increases the complexity of this fit. Finely, since many optical surfaces are rotational invariant, there is no way to proper reference the z-axes rotation out of the measurement data without additional markers. If fitting procedures are used without paying attention to this fact, the resulting relative points of origins may differ, alike the applied coordinate system.

2.2 Marker

One way to improve the precision of referencing surface metrology data sets is to add small but significant surface exaltations to the surface, which are easy to be recognised and referenced in the measurement data. Since different measurement technologies are based on different physical attributes of the surface, the design of the marker shape and technology to fulfil the high end referencing with all the required probe systems is a considerable challenge. The markers should be possible to be measured by optical and tactile probes, scanning as well as picture based methods to enables a more precise comparison between different measurement techniques. Each of these ‘markers’ should enable to reference a certain 3D-position with low uncertainty. In their location to each other, a set of at least three markers defines the complied coordinate system. This preferably works simple when metrological access to a certain feature of the marker is directly possible; e.g. finding a centre of a hole, but it also should improve the result of fitting procedures as much as the additional surface exaltation occurs in the direction of the fitting requested parameter.

2.2.1 Marker design

Recently, there have been several developments to reference measurement data sets for instance for nano inspection with AFM [1] or white light interferometry [1] and [3]. With sizes of only a few microns these markers are not recognisable by some important form measurement technologies like e.g. 3D-probes. In many picture based measurement technologies circular or ring markers are preferred for referencing. In advanced image processing, these markers are most easy to be recognised and their centre point can be found quickly by correlation methods to sub-pixel accuracy [1], no matter of the z-rotation orientation of the sample. For scanning metrology, markers are preferred, which enable a precise centre point determination with only a few measured profiles matching the markers. Therefore cross like designs are preferred [1]. They can be produced either by shaped ablation or materialization, like shown in Figure 1d.

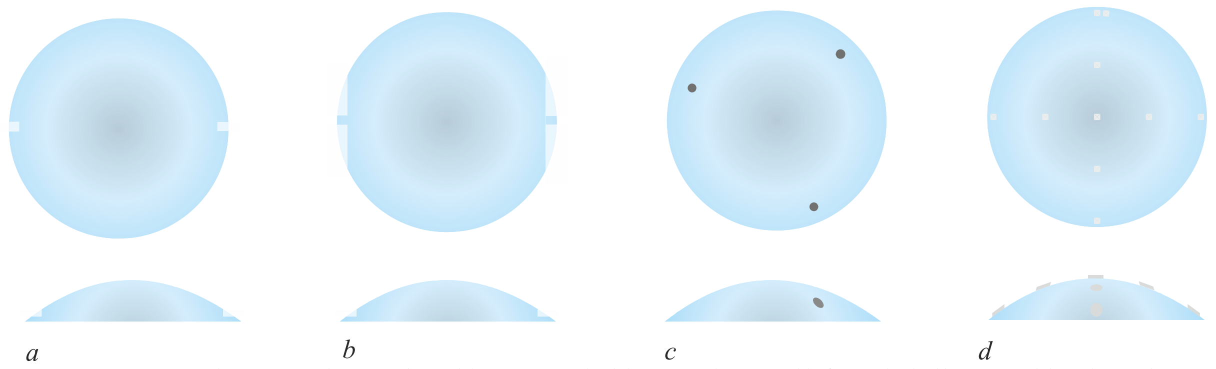

Figure 1: Marker examples produced by material ablation: a) gaps, b) fins, c) drillings and by shaped materialization d)

In 3d-probing the probe tip can be controlled to follow a once touched surface. Simple but precise manufactured geometric elements like holes, cylinders or spheres are common referencing elements. The automated calculation of the centres of these elements is implemented in most 3d-coordiante measuring software. For aspheres or freeforms some examples for markers by material ablation are shown in Figure 1a, Figure 1b and Figure 1c. Due to the size of the exaltations of the referencing elements, they are difficult to be measured with other technologies.

2.2.2 Marker production

Based on several experts' discussions in the course of the JRP IND10 Form – 'Optical and tactile metrology for absolute form characterisation' - a series of various marker structures for the alignment and position reference of aspheres and freeforms suitable for most of the surface metrology technologies have been developed at the Institute of Prozessmess- und Sensortechnik at Technische Universität Ilmenau. The production was carried out in collaboration with the Zentrum für Mikro- und Nanotechnologien in Ilmenau. Since this research centre is very familiar with lithography technology for flat surfaces, a solution for the exposure of markers for non-flat optical surfaces had to be found. It could be demonstrated, that the 'scanning lithography' of photoresist coated curved sample surface is possible using the nanopositioning and nanomeasuring machine NMM1 as a precision positioning device for the sample. For this purpose, a focused exposure laser beam with a wavelength of 405 nm was coupled and collimated into the surface scanning focus probe of the NMM1. While the focus probe is used to scan the photoresist coated surface topography of a sample lens [4], the focussed spot of the exposure laser illuminates the photoresist at exactly the same position. As the exposure line width amounts a few microns, the whole procedure can be described as line-marking exposure tracks into the photosensitive coated surface. A speed of about 15 microns per second was chosen to reduce the track errors when sharp corner marking. Thus this procedure is very accurate but quite time consuming. To exposure with the exact illuminance level, depending on traverse speed and focus size was found to be a challenge. For the control of the NMM1 numerous scripts have been developed to produce various structures with certain test properties. Figure 1Figure 2 shows the exposure tracks for a marker structure, which was optimized for a two profile scan referencing.

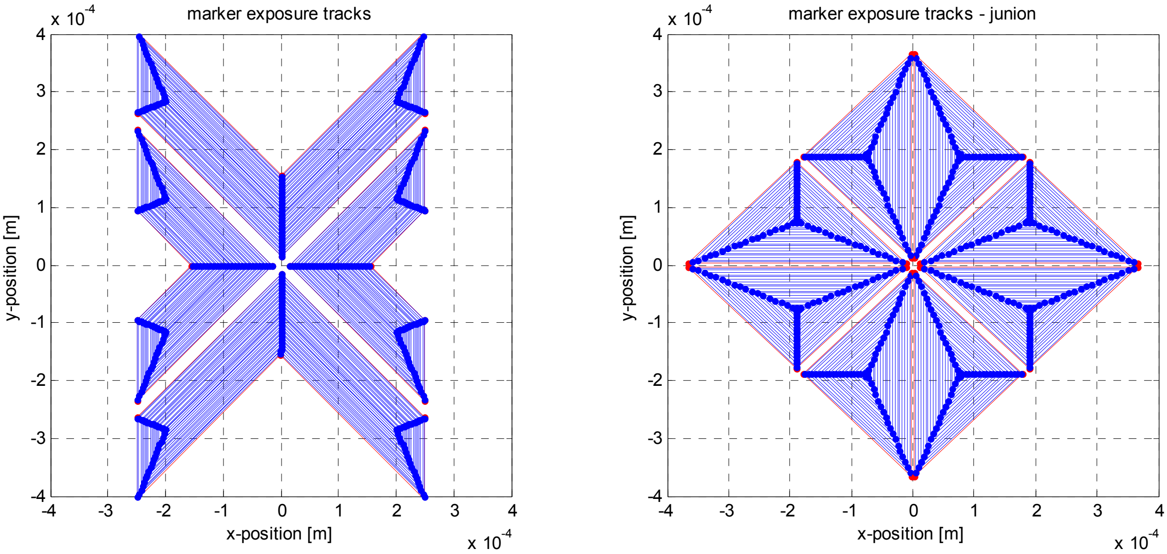

Figure 2: Exposure tracks for example markers

2.2.3 First test sample

For the first sample we used a spherical 1” lens of fused silica. If there are parts of the surface to measure outside of the later optical effective area, this would be the best places to position the markers. To explore the procedure of referencing the surface measurement data set however, we allowed every position to be used for markers on the first sample as can be seen in Figure 3a. You may recognize those of the strong cross markers in the centre region by eye sight. Each marker consists of a set of shaped metal coatings of chrome of about 200nm, leaving gaps of the original surface in between. In Figure 3b the centre part of a marker is photographed. The production process was not ideal adjusted yet and a side wall disturbance probably caused by the additionally applied coating of aluminium nitride was discovered. However the shaped marker structures have been analysed for their potential of referencing measurement data sets.

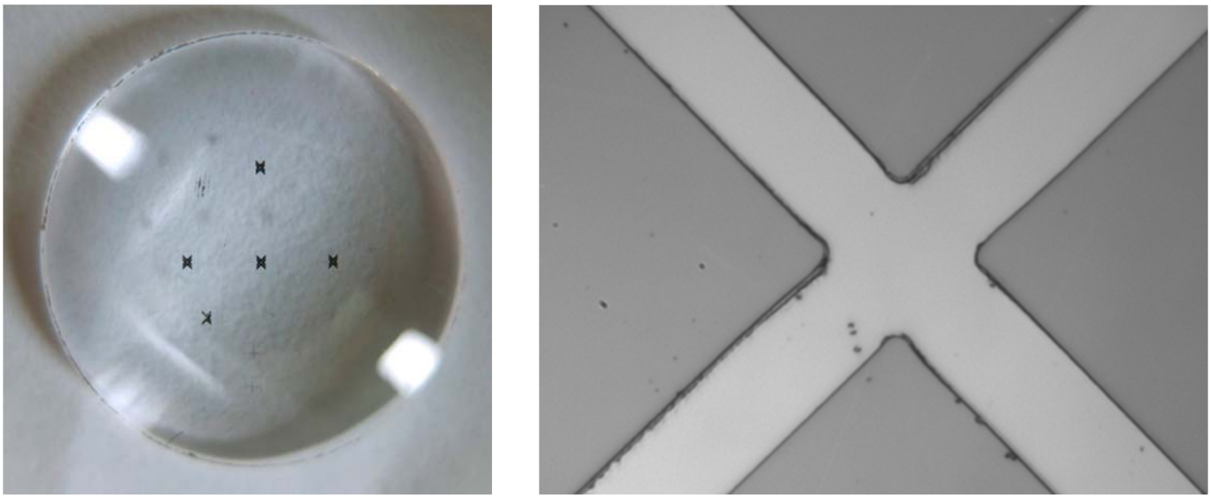

Figure 3: Markers a) on the first sample lens and b) view onto the centre cross of a marker

2.3 Measurements of marker structures

A focus sensor measurement of one of the central markers is shown in Figure 4a), a metrological AFM measurement in Figure 4b). Both measurements have been done with the NMM1. As already can be seen, the two measurements show different properties of the markers. The side wall overshoots in the AFM- measurement refer to a burr of the surface but are not to be seen in the focus probe measurements.

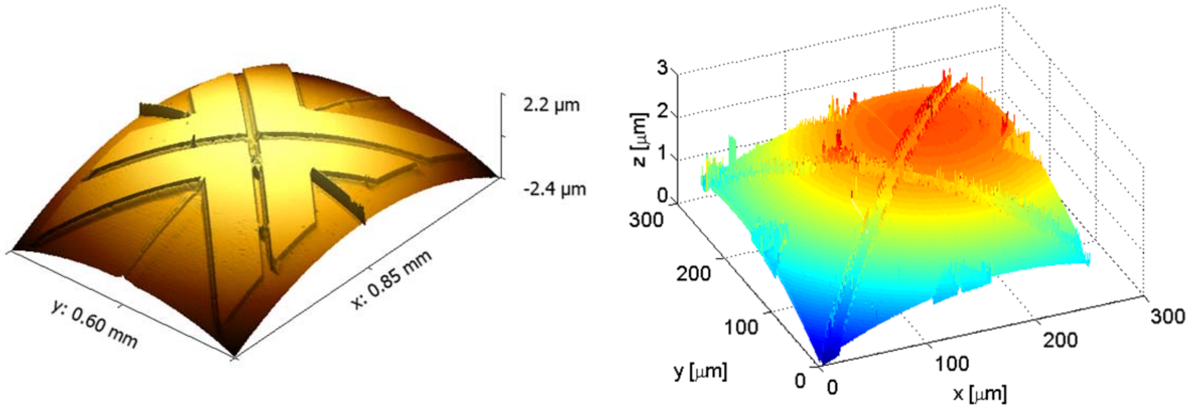

Figure 4: Measurement of a marker with a) focus sensor b) metrological AFM

2.4 Conclusion

We described the development and production of thin metal coating marker structures directly positioned on an optical surface. A new approach to exposure a photoresist coated non flat sample while scanning its surface at the same time was develop at the Institut für Prozessmess- und Sensortechnik at Technische Universität Ilmenau. The capabilities of 'scanning lithography' could be demonstrated using the nanopositioning and nanomeasuring machine NMM1 for providing the precise lateral and height position control of the sample. We gave examples of measurements of the markers with focus sensor and metrological AFM. This first experimental proof of the new technology at the same time showed a lot of potentials as well as many possibilities for the improvement of the precision.

2.5 Outlook

The markers we produced were designed to be measured with many various surface measurement technologies. Only two of them have been tested so far. The metrological feedback is still awaited for the design of the next generation of markers.

While the marker exposure tracks should be written correctly by a few nanometres uncertainty, there are some possibilities to improve the straightness of the gaps and their side walls throughout the complied lithography process. The optical and mechanical construction for the exposure beam coupling has to be improved as well as the power stabilisation and control for the exposure beam in dependence of the motion speed and focus on the sample. The ability to automated controlled power down the light without destabilising the laser diode seems to be a further challenge. To improve the precision of the marker structures, a lot of lithography process parameters and materials have to be systemised and optimised for this new non-flat technology. The potentials of exposing and coating on steeper sloped surfaces are not tested out yet.

Comparison and fusion of aspheres and freeform measurement data requires marker referencing.

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