Replica casting technique for micro Fresnel lenses characterization

Gasparin, Stefania; Tosello, Guido; Hansen, Hans Nørgaard; Albajez, J.A.

Published in:
Proceedings of the 12th euspen International Conference

Publication date:
2012

Replica casting technique for micro Fresnel lenses characterization

S. Gasparin[1], G. Tosello[1], H.N. Hansen[1], J.A. Albajez[2]
[1] *Technical University of Denmark, Denmark*
[2] *University of Zaragoza, Spain*

stga@mek.dtu.dk

Abstract

The available measuring techniques are not always suitable for the characterization of optical surfaces such as Fresnel lenses or polished specimens. A way to overcome these challenges is to reproduce the optical components surface using a polymer casting method and to measure the replicated surface. The aim of this paper is to investigate the replica technique when applied to micro structured specimens such as moulds for injection moulding of Fresnel lenses. Stability studies, replication fidelity investigations and dimensional measurements were performed in order to validate the performance of the replication method.

1 Introduction

Recent studies have shown unsolved challenges in finding a suitable measuring instrument for the characterization of optical components. Contact measurements cannot be performed without damaging the high surface finishing of the component, while optical measurement techniques might not be accurate due to high surface slopes and reflectivity. The proposed solution is the use of a replica casting method. This technique has been successfully applied to different topography purposes [1], e.g. for the characterization of micro-structured optical components [2] and for roughness standards in order to obtain surface traceable measurements [3]. In this paper, the investigated specimens were two mould inserts used for the production of micro Fresnel lenses through an injection moulding process. The aim of the study is to investigate the performance of the replica technique (i.e. stability study and visual comparison) and to evaluate the wear of one selected micro feature on two lenses. The replicas were measured using an optical instrument based on the focus variation principle and inspected through scanning electron microscope (SEM) imaging.

2 Case description

The two mould inserts were designed for a miniaturized portable lighting device for digital imaging, characterized by six pairs of lenses. They were both made of nickel (Ni) and one had a titanium nitride (TiN) coating on the surface, see Figure 1, left. The two moulds were monitored while running 24500 injection moulding cycles and replicated at different production stages in order to characterize the dimensions and wear of one micro features (i.e. centre geometry, see Figure 1, right). The tools surfaces were also reproduced using a soft replication casting technique. The used compound was supplied in cartridges containing both the polymer and the curing agent, which were automatically mixed in a disposable static-mixing nozzle during the application on the surface to be replicated. After few minutes the resulting soft-compound was removed from the surface and a replica of the specimen was obtained. Both mould inserts were cleaned using acetone prior the soft replication step to avoid that polymer residuals could affect the replication fidelity of the surface.

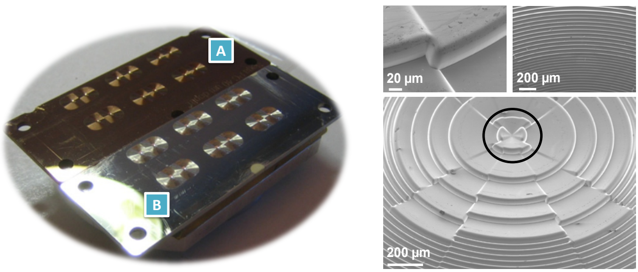


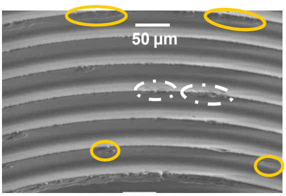
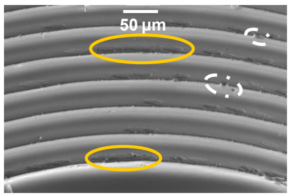
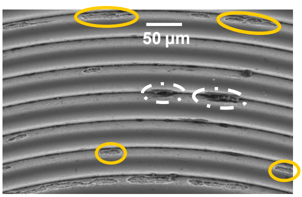
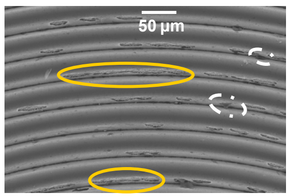
Figure 1: Fresnel lenses moulds used for the replica casting investigation. Left: (A) Ni insert with TiN coating, (B) Ni insert. Right: overview and details of one lens. The circle highlights the investigated centre geometry.

3 Results

Stability studies were performed in order to ensure the reliability of the replica over two periods of time: 180 minutes and 14 days. One lens of one replica was measured using the focus variation optical instrument. The measurements were performed on the ribs of the centre geometry, characterized by an average height of 35.5 µm. An automatic procedure was applied through a height distribution method in order to exclude the influence of the ribs sidewalls. During the entire experiment, the replica was kept in a clean environment with a constant temperature of 20 ± 1 °C. Results showed a stability range (i.e. standard deviation of the measurements) within 0.1 µm during 180 minutes and 0.5 µm during 14 days. Moreover 10 measurements were repeated in the same spot showing a standard deviation of 0.1 µm.

After 24500 moulding cycles, an SEM inspection was carried out on the moulds replicas and on the two inserts in order to have a visual estimation of the replica fidelity. The SEM pictures were taken in a very precise spot of two lenses: one close to the injection gate and one far from the injection gate. This precise spot was selected in order to guarantee a direct comparison between the mould and the replica-mould. Table 1 summarizes the most important results concerning the TiN coated mould. The yellow solid circles indicate wear on the coated mould; while the white dash-dot circles indicate residuals of polymer material from the injection moulding process. It is evident that the replica was able to reproduce the worn areas of the tool but also the polymer stuck on the mould surface. In fact particles of polycarbonate were found every time a replica was made.

Table 1: SEM imaging taken in the same spot of two different lenses (close/far the injection gate) in the TiN coated mould and in its replica after 24500 cycles.

	Close to the gate	Far from the gate
Replica		
Mould		

The tool wear was analyzed by means of dimensional measurements of the ribs height on the replica during 24500 moulding cycles. The dimensional measurements were carried out every 1000-2000 cycles on two selected lenses of the two moulds: one close to the injection gate and one far from the injection gate. Results are summarized in Figure 2. As can be seen, no substantial wear was detected for the coated and uncoated mould and no actual variation was observed between the two lenses (close/far the injection gate). The traceability of such measurements on soft replicas was previously investigated on dimensional reference standard objects. The expanded combined uncertainty was estimated equal to 0.4 μm [3].

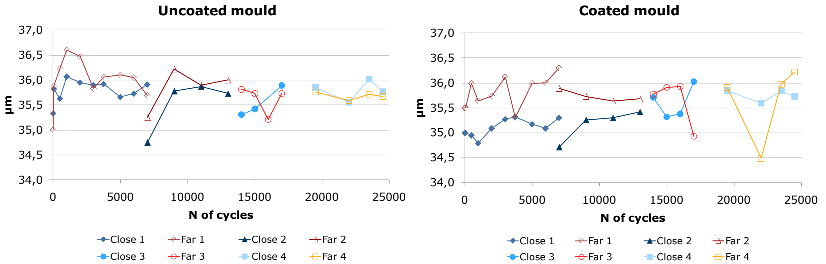


Figure 2: Average height of the ribs on the centre geometry measured on two different replica lenses (close /far from the gate) during four time periods of the entire production of 24500 cycles for Ni uncoated (left) and TiN coated mould (right).

4 Conclusions

A replica casting technique was applied to micro structured moulds for the injection moulding of optical components. The obtained replicas revealed high replication fidelity of the actual moulds and good long term stability. The replica material was also able to reproduce both the areas affected by tool wear as well as the polymer residuals from the injection moulding processes. This technique has proven to be an effective method for the characterization of micro optical surfaces.

Acknowledgements

This paper reports work undertaken in the context of the project “COTECH - Converging technologies for micro systems manufacturing”. COTECH (http://www.fp7-cotech.eu/) is a Large Scale Collaborative Project supported by the European Commission in the 7th Framework Programme (CP-IP 214491-2).

References:

[1] H.N. Hansen et al. Replication of micro and nano surface geometries, Annals of CIRP, 2011 60(2): 695–714.

[2] S. Gasparin et al. Replication quality control of metal and polymer micro structured optical surfaces, 4th SPS, 2011, pp. 533-539.

[3] S. Gasparin et al. Traceable surface characterization using replica moulding technology, 13th Met&Props, 2011, pp. 310-315.