Polishing performance of 3D-printed multi-material photopolymer tools on glass

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Abstract. Due to the increasing demands and complexity of optical glass components to be processed in the future, advanced technologies and precision machining methods will be required in order to produce high-quality optics economically. The polyjet process enables the production of 3D printed gradient index (GRIN) polishing tools with hardness gradients by combining different polymer materials for e.g. synchrospeed polishing. In terms of their geometric design, these tools are significantly more flexible than conventional ones, where the polishing cloth must be glued to metal tool holders. The composition of the polishing pad material directly influences the process efficiency and quality at which the glass is polished. In a laboratory test the influence of the mechanical properties of the multi-material pads on process efficiency, i.e. their long-term stability and the polishing rate of the glass workpiece is demonstrated.

1 Introduction

A new concept for additively manufactured tools to polish optical glasses was introduced in our previous work [1]. The aim of this publication is to provide an insight into the performance of these pads for synchrospeed polishing of N-BK7 and H-K9L glasses. The pad material consists of two UV light-curing components that can be mixed in different concentrations [2]. The set mixture determines the mechanical properties of the photopolymer material and thus makes it possible to set defined hardness in mono material pads or even hardness gradients in a “GRIN” multi material polishing pad.

2 Experiments

2.1 Polishing setup and parameters

Figure 1 shows the test setup and the parameters that have been chosen for the tests, each lasting 60 minutes. The suspension used is Hastilite PO, which is stirred in a 0.5 litre container by a rotating magnet. With an average diameter of 28 mm of the polished ring on the glass substrate and the rotating speed of the polishing plate of 600 rpm, the relative polishing speed is 0.84 m/s.

The glass samples are weighed before and after the test to determine the mean mass that was removed by different polishing pad compositions. This allows the volume removal to be calculated, taking the glass density into account. A similar method is proposed in [3].

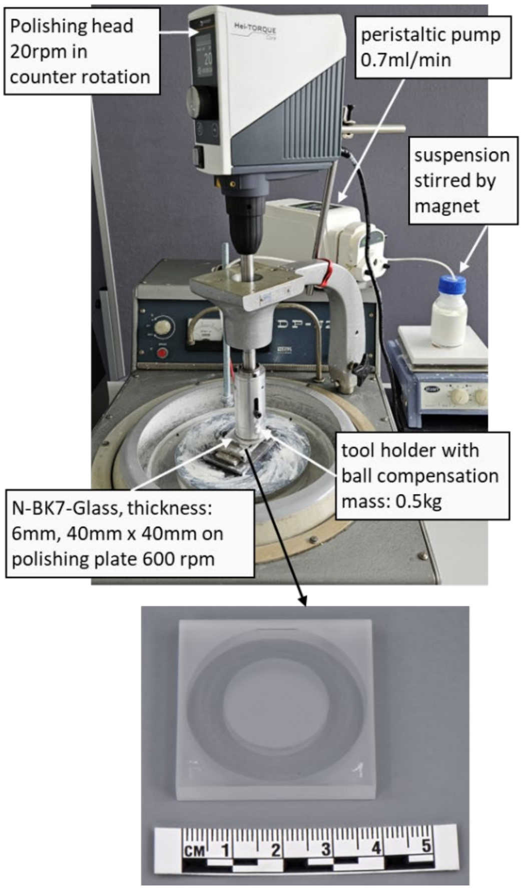

Fig. 1. Experimental setup and sample of polished glass substrate of H-K9L

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2.2 Polishing tools

The structure of the polishing tools, that are 8 mm in diameter, is shown in Figure 2. The carrier of the pad is always made of the hardest component in the system called “VW", i.e. only the polishing pad material is varied by adding the component called “TB+” in defined proportions. The structure of the pad with the cross-shaped channels enables a sufficient supply of polishing agent between the pad and the glass surface. The support ring stabilises the pad, leads to a longer service life and serves as a stop so that the pad is always positioned at the same height in the tool holder.

As reference a conventional polyurethane pad of type GR35 is glued on a steel stud, which is fixed in the tool holder in the same way as the other tools.

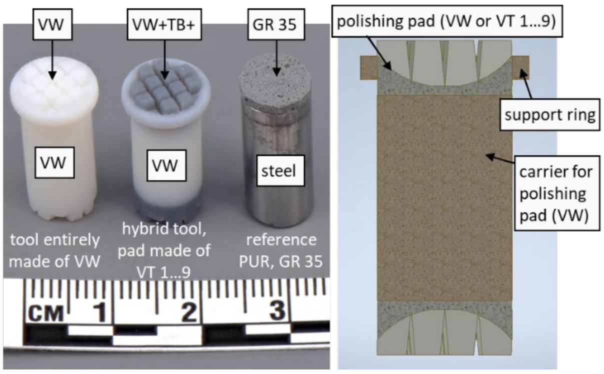

Fig. 2. Composition and geometry of the polishing tools.

3 Results

3.1 Polishing rate of the tools

Figure 3 shows the glass volume removal rate generated by the test described above for different material compositions. In addition the hardness range Shore D according to the datasheets of the material manufacturer is plotted. Ten different compositions of “VW” (hard polymer with 83-86 Shore D) and “TB+” (soft polymer with 26-28 Shore A) have been tested. They are listed on the x-axis of the diagram.

The strongest decrease in removal rate correlates with the decrease in hardness. Compositions with hardness below 70 Shore A, which corresponds to 18 Shore D, are not tested. In these cases the pad material of the tools is too soft and not resistant enough to achieve a constant polishing quality over a process duration of at least five hours.

The highest glass volume removal rate is achieved for the composition “VT 4”. It is comparable to the conventional reference polyurethane pad GR35. The lowest value, however, is determined for "VT 8", which corresponds to a hardness value of around 29 Shore D.

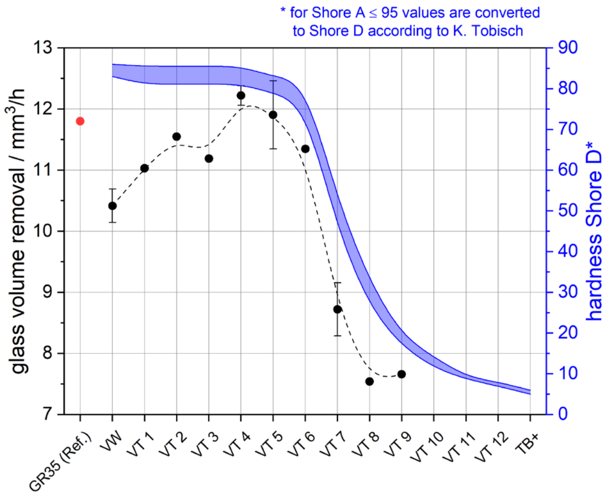

Fig. 3. Glass removal rate depending on the composition of the pad material. Hardness Shore D values according to materials datasheet. If Shore A was specified, these values were converted to Shore D.

3.2 Surface quality

Average Roughness values of Sq = 1.9nm ± 0.5nm have been measured on the polished glass surface which is also comparable to the reference surface quality of conventional tools.

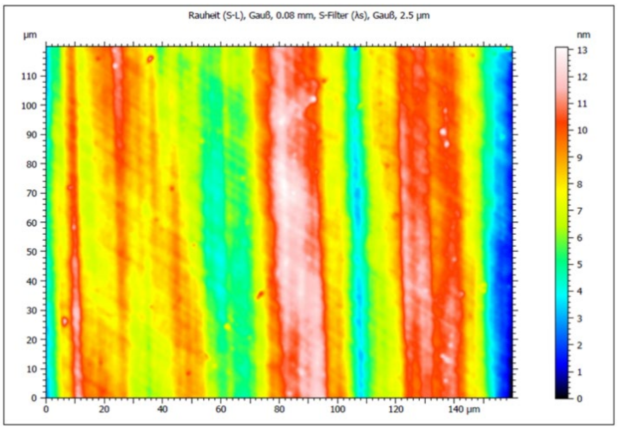

Fig. 4. Surface topography measured with white light interferometry.

References

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