Development of a process chain for silicon carbide mirrors

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Abstract

This contribution presents current results on ultra-precision grinding and polishing of silicon carbide for mirrors, which has been investigated within the research project MirrorFab. The effects of different grinding wheels and process parameters on the shape accuracy, surface roughness and the grinding forces are discussed. It turned out, that surface qualities in the range of 10 nm Rms can be achieved with appropriate parameters. In polishing, the focus is set to the investigation of the effects of various polishing pads and slurries on the material removal rate and surface roughness. Two combinations (polishing pad and slurry) are recommended, one features a high material removal rate for fast removal of grinding marks and the other one a low surface roughness for final smoothing. The presented results enable a systematic adaption of the grinding and polishing processes to the varying requirements in manufacturing silicon carbide mirrors.

1 Motivation and technological background

Different grades of silicon carbide (SiC) became an established material for structural components as well as optical mirrors in space-borne applications [1]. Although such mirrors offers additional benefit to further applications, the high manufacturing efforts restraint an extended application to further fields, such as air-borne applications or in machining technologies. Therefore, the collaborative research project MirrorFab aims for a qualification of an optimized process chain for manufacturing mirrors made of Cesic®. This material consists of a matrix of SiC reinforced with microscopic carbon fibers [2]. There is a space qualified Cesic® manufacturing process and an established network for the supply chain. The project addresses the required gain in efficiency and flexibility in manufacturing mirrors.

Goals consist in increasing the performance of each technology within the manufacturing sequence as well as in an optimum coordinated sequence in total. This paper deals particularly with the process optimization in grinding and pre-polishing.

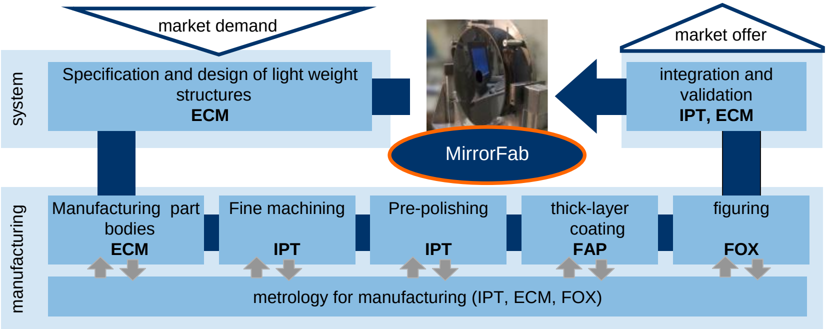

Figure 1: Idea of "MirrorFab" and approach within the consortium

2 Investigation of ultra-precision grinding of silicon carbide

2.1 Experimental set-up and procedure

Within the project the use of an ultra-precision grinding machine (Moore Nanotech 500 FG) was evaluated. A parameter study is performed for investigating the effects of the grit size and type of bond of the diamond grinding wheel as well as the impact of the process parameters cutting speed, cutting depth and feed rate. Output parameters are the shape accuracy, the surface roughness and the grinding forces.

Fig. 2: Used machine tool, force measurement equipment and grinding cinematic

The two grit sizes D46 and D6 of diamond abrasives and the bond types resinoid and bronze were combined to four types of grinding wheels. For the measurement of the grinding forces a rotating 4-component dynamometer for cutting force measurement (Kistler, type 9223) was placed on the sample chuck under the work piece.

In order to minimize the efforts needed to carry out the experiments, but assure a statistical relevance at the same time, the method „design of experiments“ is used to make up the table of experiments to be performed for each grinding wheel.

2.2 Results and discussion

Figure 3 illustrates the so called main effects of the given parameters on the average surface roughness Rz. The investigation of the effects of the major machining parameters (cutting speed, depth of cut and feed rate) reveals the expected behavior. A higher cutting speed and a lower depth of cut result in higher surface quality and therefore less sub-surface damages. The feed rate does not show a significant effect under the given conditions. An evaluation of the main effects diagrams shows qualitatively the same trends for the Rms.

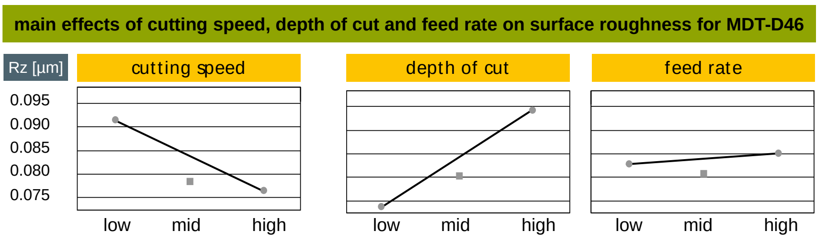

Figure 3: Main effects of process parameters on the surface roughness Rz.

A comparison of all investigated grinding wheels reveals that the use of the grinding wheel with the larger grit size D46 and a resinoid bond generates the lowest surface roughness. The surface quality is even superior to the one after machining with the grinding wheels featuring a smaller grit size of D6. Concerning the mechanical load on the sample caused by the grinding forces, it is found that the tangential forces are approx. 2 N and the normal forces around 6 N.

3 Parameter study on polishing silicon carbide

The investigation and optimization of the polishing step concentrated on the determination of appropriate combinations of the polishing pad, the abrasive and the process parameters. In the experiments, five different pad (three polyurethane by

Universal Photonics, one fabric and one felt) and three types of diamond abrasives were investigated with two set of process parameters. The right graph in figure 4 illustrates the achieved surface quality, described by the Rms.

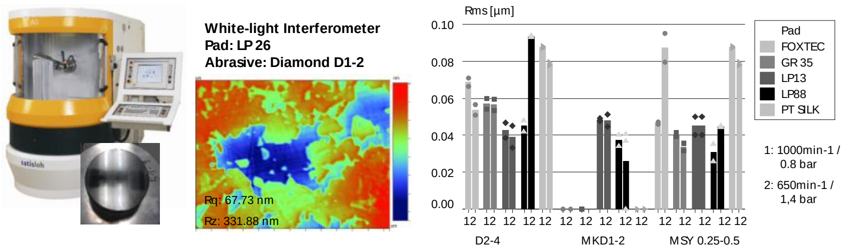

Figure 4: Experimental set up and results of experimental study on polishing Cesic®

The experiments reveal that the use of a soft polyurethane pad (LP 13) and a diamond slurry with a grit size between 2 and 4 µm represent a suitable trade-off between material removal rate for efficiency and sufficient surface quality for the following machining steps. The lowest surface roughness can be achieved with a hard polyurethane pad (LP-88) and very fine diamond abrasives.

4 Summary and Conclusion

This paper presented the results of the investigation of a fine grinding process of the material Cesic® on an ultra-precision grinding machine. Four grinding wheels were investigated. Based on the parameter study, appropriate parameters according to the requirements of the complete process chain can be chosen. Within the project MirrorFab, the pre-polishing process is also systematically investigated and optimized in regard to the polishing system at Fraunhofer IPT.

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References:

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