Grinding Processes for Silicon Carbide (CSiC) Materials

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Abstract

The individual production of optical parts is usually done by using the steps of pre machining (e. g. the sawing of the rough parts) pre grinding, fine-grinding and polishing. The pre-machining and grinding processes only provide rough blanks with geometrical deviation up to hundreds of microns (1). Polishing processes provide removal rates up to several microns per hour, depending on geometry, material and process (2). As the material removal rates of polishing processes dealing with common materials (e.g. glass) are relatively high, the necessary quality achieved within the rough machining processes is less important. The final quality is performed by the polishing processes. The group of so called ceramic matrix composite materials (CMC), such as silicon carbides or silicon nitrides, gets more and more important. Carbon fibre infiltrated silicon carbide, is one of this CMC materials that can hardly be polished using soft tools, such as polyurethane foil. It consists of soft areas of pure silicon and hard areas of silicon carbide (3). The material's structure is a result of the production process. This inhomogeneous structure makes the polishing process very difficult. The removal rates are relatively low and common polishing processes, dealing with soft poly urethane foils, tend to erode the softer silicon. Therefore the performance of the grinding process gets more important.

1 Introduction

Due to further development of applications for optical systems, the requirements on materials for optical components have increased. The marked offers several types of advanced materials with nearly perfect physical and mechanical properties for high-tech-applications. Some of them where originally developed for the aerospace industry and for military purposes. They can withstand high mechanical and thermal loads at low deviations. SiC based materials are also of low density at high hardness and bending strength. After the SiC-blanks are compounded they can only be further machined using diamond grits, e.g. ground and/or polished. Several companies, such as ECM (4) and SGL (5) offer carbon fibre infiltrated silicon carbide materials (C/C-SiC), which are being used for light weighted space telescope mirrors (6) and sports cars brake discs (3) as well. Machining a CSiC blank for a space telescope mirror can last more than a year, due to very low removal rates. In order to make production processes for C/C-SiC compounds more efficient, the University of Applied Sciences "Hochschule Deggendorf" investigated suitable processes.

2 Experimental setup and procedure

Points of interest in machining SiC materials for optical parts are achievable surface roughness using grinding processes, form deviation, tool wear, and structural damages. In order to evaluate the efficiency of the chipping processes several series of samples were conducted:

The task was to find out how to reduce the surface roughness on C/C-SiC blanks. Therefore grinding experiments were conducted, using ball-shaped tools (small area of contact). These are commonly used for non spherical and freeform shapes. In addition to that, test runs using flat grinding wheels (large area of contact) were conducted as well. For the test runs with ball shaped tools an OptoTech ASM 100 grinding machine was used. Resin and metal bonded tools with diamond grits where tested on pure SiC samples and C/CSiC samples. The samples ground with the ASM 100 where machined in spiral mode with ball shaped tools with diamond grits, metal bond and, resin bond as well. In order to keep the chip thickness low the feed rate was slowed down to 1 m/min at a spiral distance of 0.1 mm. To keep the temperature low, the cutting speed was adjusted to 12.6 m/sec. The depth of cut was 20-30 µm.

Fig. 1: ASM 100, tools and strategy

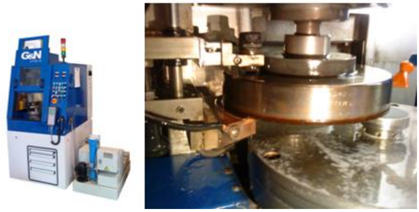

Fig. 2: G&N VTS-3

The machine used for flat-grinding-experiments is a G&N VTS-3. It's a prototype, originally developed for machining silicon and sapphire wafers with ELID processes (electrolytic in process dressing) (4) (5). It is a highly rigid machine which uses relatively large (diameter 175 mm) cast iron bonded grinding wheels with diamond grits. The sample with the lowest surface roughness was additionally polished with polyurethane foil and Ceroxid to lower the surface roughness.

3 Results

The results show a decreasing surface roughness according to the order of the chosen chipping processes. The lowest roughness measured was approximately 6 nm rms, which is quite good – even for an ELID-process. The most remarkable result was a roughness increase through the polishing process.

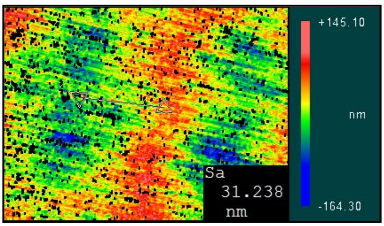

Fig. 3: Cesic ground, D20 metal bond

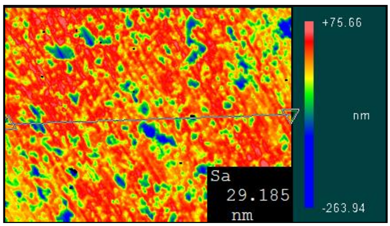

Fig. 4: CSiC ground, D14 resin bond

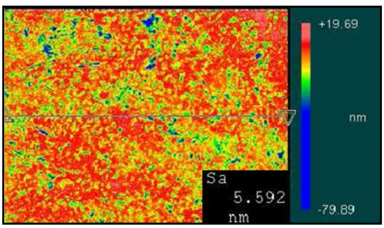

Fig. 5: CSiC ground, ELID D3

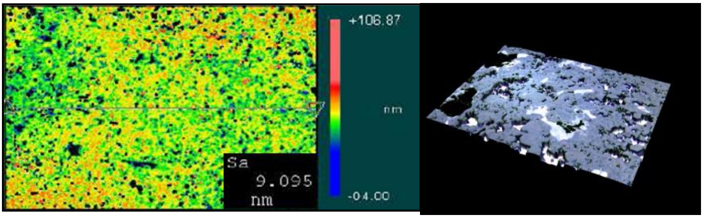

Fig. 6: C/C-SiC polished, polyurethane foil and Ceroxid

4 Conclusion

According to the results, it is possible to improve the achievable surface quality via grinding with hard tools. Therefore the tools must be adopted for the special material characteristics of CMC's. Especially the ELID processes are very suitable for inhomogeneous materials, due to the extraordinary good results. The grinding tool for ELID-processes consists of rigid cast iron, which renders the tool itself relatively hard. The soft and thin oxide layer performs the good results concerning the surface roughness, achieved during the test runs. The common method to generate rough blanks using grinding processes and correct them with polishing processes using soft tools seems not efficient for this kind of materials. The roughness increase after polishing is probably a result of the materials structure, as it consists of softer silicon (easy to polish with high material removal) and harder silicon carbide (time consuming to polish).

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