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Preparation of surface micro-structured coarse-grained diamond wheels based on high efficiency mechanical conditioning and picosecond pulsed laser machining

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Abstract
The conditioned coarse-grained diamond wheels are able to achieve the identical surface roughness, higher form accuracy and larger material removal rate on optical glasses while larger grinding forces and deeper subsurface damage depth also could be inevitably introduced due to the flat tops of the coarse diamond grains. In order to overcome this problem, the precision grinding technique of optical glasses with micro-structured coarse-grained diamond grinding wheels was developed in recent years. This paper introduces a method for preparing surface micro-structured electroplated coarse-grained wheels. A high efficiency mechanical conditioning based on vitrified fine-grained diamond wheel for electroplated coarse-grained diamond wheel is introduced, firstly. Subsequently, 4 micro-structure surfaces with different micro-structure patterns are obtained by laser micro-structuring with picosecond pulsed laser. At last, three surface micro-structured electroplated coarse-grained diamond grinding wheels were successfully prepared based on the conditioning method introduced in this paper and micro-structuring with picosecond laser.

Keywords: Precision grinding, Coarse-grained diamond, Laser micro-structuring, Electroplated wheels, Optical glasses

1. Introduction

The conditioned coarse-grained diamond grinding wheels are possible to achieve the identical surface roughness, higher form accuracy and higher material removal rate on optical glasses owing to their much larger cutting edge width, better wear resistance ability, and bigger chip space as compared to the traditional fine-grained diamond wheels [1-3]. However, bigger grinding force especially normal grinding force also could be inevitably introduced due to the larger flat top surface of the coarse abrasive grains [4-6]. For overcoming this problem and achieve high-efficiency precision grinding of optical glasses simultaneously, a new deterministic grinding process with surface laser textured or micro-structured electroplated coarse-grained diamond grinding wheels was introduced.

Our previous work indicated that the laser micro-structured coarse-grained diamond grinding wheels with regularly micro-grooves in the circumference direction have a considerably improvement for the subsurface damage of ground BK7 glass [7]. However, the preparation of micro-structured coarse-grained wheels is still a huge challenge. In this paper, a modified method for preparing micro-structured coarse-grained diamond grinding wheels is presented.

2. Experimental setup

The grinding and conditioning setup is shown in figure 1(a). A vitrified fine-grained diamond wheel is applied in this research as a conditioning wheel. The coolant is emulsion.

The laser micro-structuring setup, as shown in figure 1(b), was composed of a picosecond laser source, focus lens, CCD cameras and a 4-axis precision translation stage (position accuracy 0.1μm). A picosecond pulsed laser of wave length 532nm, pulse width 800ps, pulse repetition frequency 1-5kHz was taken for micro-structuring the grinding wheels.

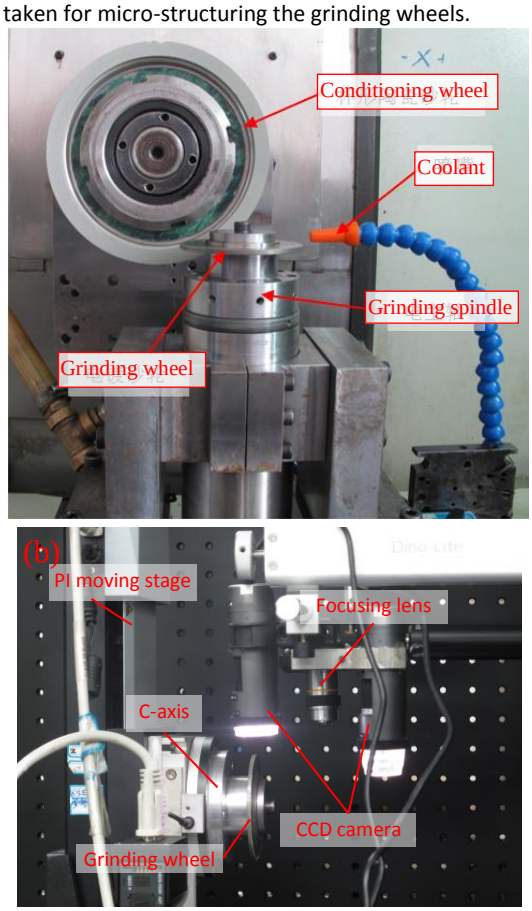

Figure 1. Machine tool configuration for polishing (a) conditioning and grinding setup (b) laser micro-structuring setup.

3. Research results

3.1. Conditioning coarse-grained diamond grinding wheels

The electroplated coarse-grained diamond grinding wheels of abrasive size 70# were conditioned by a vitrified fine-grained diamond cup-shape conditioning wheel and several BK7 glass work-piece were ground after different truing depth. In the conditioning process. The grinding wheel translated in the X-axis and in-feed in the Z-axis per pass with 1μm. Therefore, the higher diamond grains were more and more truncated and remains a flat top surface.

As described in Figure 2, the conditioning operation shows an important influence on the ground surface topography. The work-piece surface obtained before conditioning exists obvious groove profiles and the large white areas in the surface means the material were removed mainly in brittle regime. As the truing depth increasing, the ground surface becoming more and more smooth. The surface roughness obtained after 150μm truing depth measured by atom force microscopy (AFM) is Ra 3.6nm and Ra 1.1nm in the vertical and parallel direction to the grinding direction, respectively. The total conditioning time less than 3 hours. Therefore, conditioning electroplated coarse-grained diamond grinding wheel with the technique introduced in this paper is effective.

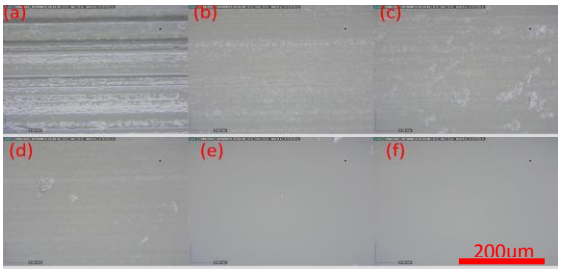

Figure 2. Ground work-piece surfaces obtained after 0μm and 180μm truing depth (a)0μm (b)30μm (c)60μm (d)90μm(e)120μm(f)150μm.

3.2 Laser micro-structuring diamond surface

Laser micro-structuring diamond surface with the defined micro-structure patterns and structuring ration (the proportion of the area remained after micro-structuring) is meaningful and very important for the final micro-structuring process. Four different micro-structured surface is successfully fabricated on diamond surface as shown in figure 3. The laser machining parameters is scanning speed 0.25mm/s, average power 80mW, repetition frequency 5kHz and off-focus quantity 0μm and the groove width is about 20-30μm which obtained by scanning 3times with an interval of 6μm between each scan. It is clear that machining diamond surface with picosecond laser with sharp edge and acceptable surface quality is feasible.

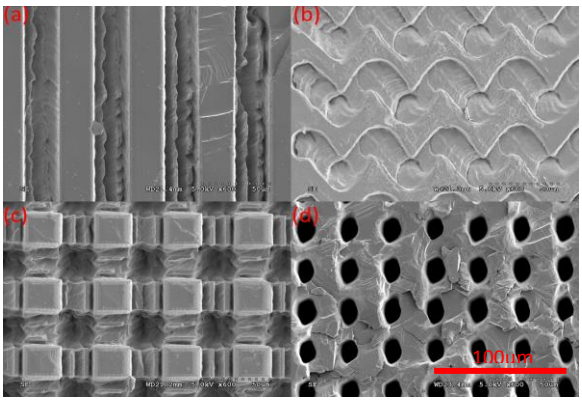

Figure 3. Different micro-structure patterns on diamond surface (a)parallel line (b) wave line (c) cross line (d)dot array

3.3. Micro-structuring grinding wheels

After the conditioning operations and laser micro-structuring diamond surface experiments, three surface laser micro-structured electroplated coarse-grained diamond grinding wheels of structuring ratio 66.7% with different micro-structure patterns(parallel lines, inclined lines, cross lines) were prepared as shown in Figure 4. The groove width of these patterns was 30μm and the interval between two adjacent grooves was 120μm for the parallel-line pattern and 145μm for the cross-line pattern. In the incline parallel lines pattern, the groove direction had an angle 45° with the wheel axis direction. The diamond grains located on the grinding wheels' surface is effective micro-structured and be divided into two or more zones. The groove existed on the abrasive grain tops effective reduces the contact area between work-piece surface and the abrasive grains on wheel surface but remains the cutting edge almost intact in the grinding direction.

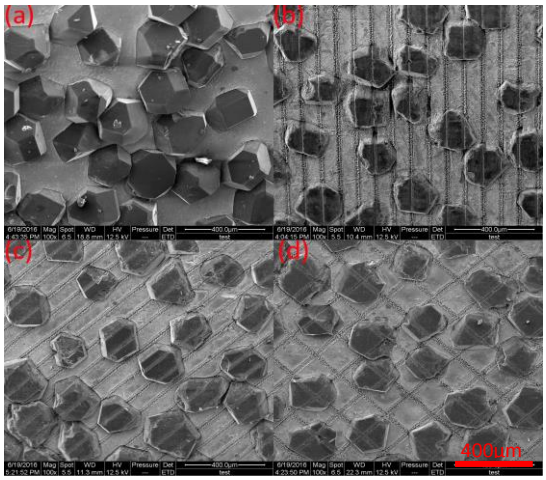

Figure 4. Coarse-grained electroplated diamond grinding wheels (a)not-conditioned wheel (b)parallel lines (c)inclined lines (d)cross-lines

4. Conclusions

In this paper, a modified method for preparing micro-structured coarse-grained diamond grinding wheels is introduced and the conclusions can be concluded as follows:

(a) The mechanical conditioning with vitrified fine-grained diamond wheel for coarse-grained diamond grinding wheel is an effective technique;

(b) The picosecond pulsed laser could be used for improving the micro-structures accuracy on diamond wheel surface;

(c) Three surface micro-structured grinding wheels with parallel lines, inclined lines, cross lines were successfully fabricated.

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