

# Polishing experiments of thin mirror with magnetic medium assistant polishing technology

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The thin mirrors are widely used in active optical system. In this letter, magnetic medium assistant polishing (MMA) technology and device are discussed for thin mirrors optical finishing. The principle of MMA is introduced, the magnetic tool for polishing is designed, and the removal function of magnetic polishing tool is studied. On the basis study of the material removal function especially removal property in the edge region, the tool-path is optimized, and the dwell time distribution of computer-controlled MMA is researched. The glass thin mirror is polished by MMA technology. The diameter of the work-piece equals S22201 150 mm and the thickness is 5 mm. The initial surface error is  $0.19 \lambda$  (root mean square (RMS)), and after two steps fabrication, the final surface error reaches  $0.02 \lambda$ . The experimental results verify that the technology is effective for thin mirrors finishing.

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Nowadays the thin mirrors were widely used in active optical systems. In tradition optical fabrication, the tool would make a vertical press on the thin mirror surface, and the thickness is not strong enough, so the surface would get lots of prints caused by polishing tools. It is difficult to improve the precision of the mirror by tradition polishing methods. Our laboratory work together with Belarus researchers and developed a new magnetic medium assistant polishing (MMA) technology<sup>[1,2]</sup>. The tool makes shear force instead of vertical press to removal materials. It avoids the deformation of the thin mirrors in polishing.

The tool just like a wheel and magnetic field is specially designed<sup>[3,4]</sup>. The maximum magnetic density zone is on the middle surface of the magnet-wheel. Then the magnetic medium which put on the wheel surface became salient as a brush polishing tool. While polishing the surface, the wheel rotated with high speed, and the magnetic medium brush removed the materials combine with the circulatory polishing abrasive fluid. The magnetic medium brush was working as the bitumen pad in computer controlled optical surfacing (CCOS) which contain the abrasive parts. The advantage of MMA is that the shape and character of the tool are invariable in the fabrication. Because the designed magnetic field made the brush recovery automatically, the tool removal ability was stable and makes no vertical press on the thin mirror surface.

The magnetic wheel is the most important part of the device. In the fabrication, the magnetic medium put on the surface of the wheel, arranged with the line of magnetic force and stood up. The magnetic mediums became salient as a brush polishing tool and made shear on surface. The tool rotated and moved over the surface to remove the materials. The shape and character were invariable. Because the designed magnetic field made the brush recovery automatically, the interval between the tool and the surface should be constant in order to make the removal invariable<sup>[5]</sup>.

The MMA is described as Fig. 1. In the process-

ing, the polishing fluid was spurted into the tool contact area. Furthermore, the polishing fluid was produced by the abrasive powder put in the distilled water. The stabilizing agents and dispersing medium should be used to avoid the abrasive parts precipitating. The PH value was kept between 9 and 10 to make the fluid alkali. The alkalinity polishing fluid would avoid the magnetic medium oxidized in the processing. The microcosmic shape of the magnetic medium granule was similar to sphere and the cusped edge of the magnetic medium granule is few to removal the materials. So the removal influence of magnetic medium itself was very small, the chief factor of removal was caused by the abrasive in the polishing fluid.

We did the removal function experiments. The device was connected to the computer numerical control (CNC) machine. So the tool has ability of moving with

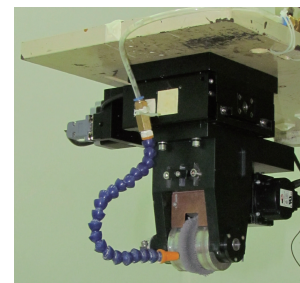


Fig. 1. (Color online) The tool of MMA device.

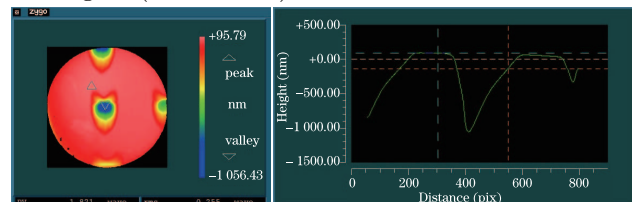


Fig. 2. (Color online) The removal function of MMA.

$x$ - $y$ - $z$  coordinate system. The diameter of the magnetic wheel is 60 mm, the type of magnetic medium is PF

40/0 Fe-based soft magnetic powder. The polishing fluid is the suspension of the  $\text{CeO}_2$  and particle size is about  $1 \mu\text{m}$ . The mass ratio of  $\text{CeO}_2$  in the polishing fluid is about 2.5%. The rotation speed of the magnetic wheel is 500 r/min. The distance between the magnetic wheel's bottom and the work-piece surface is 4 mm. The work-piece for the removal function experiment is plane and the material is K9 glass.

We took one removal function spot to see the distribution. The time of the removal was 1 min, with the rotation speed of the magnetic wheel keeping at 500 r/min. The result was measured by the ZYGO GPI interferometer. The surface error before removal should be tested and set as the system error in the software. Then the experiment finished, the surface error measured again, and the surface error after removal subtracted the system error which equaled the surface error before removal. Then the result equaled the removal of the experiment. The key point of this method was that the position of the work-piece in measuring should be the same as first measurement exactly. As described in Fig. 2, the removal function in the center of the work-piece is not similar as the traditional circular distribution. The distribution of removal function is irregular, one dimensional is symmetric but the other dimensional is asymmetric and still single peak.

The other three removal functions researched the special removal ability while polishing in the edge region. The wheel rotation direction was the same as the spot in center, but just the upon removal function consisted with the center removal function. The results described that the moving direction should be inside to outside and same with the wheel rotation direction.

Because the MMAP just make shear force at the mirror surface, this ability is important for thin mirror polishing. The diameter of the glass work-piece is 150 mm and the thickness is 5 mm. The thin mirror firstly was glued on holder and polishing by traditional method. As we know, there have inner stress between thin mirror and holder, therefore, the surface error will change a lot after the mirror take off the holder. Then we can polish the thin mirror by MMAP, as shown in Fig. 3.

We use the same polishing parameters with the removal function experiments. As described in the results, the edge removal function would be different with the center unless the move path was specially designed. Figure 4 shows the tool-path for the polishing of the thin mirror. It was combined by grating style and polar path. In order

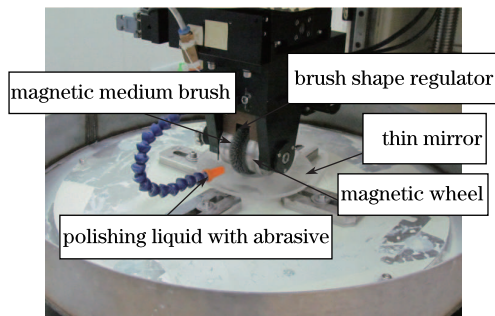


Fig. 3. (Color online) The thin mirror is polished by MMAP.

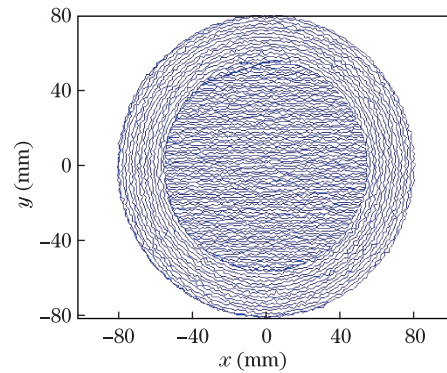


Fig. 4. The tool path for polishing thin mirror.

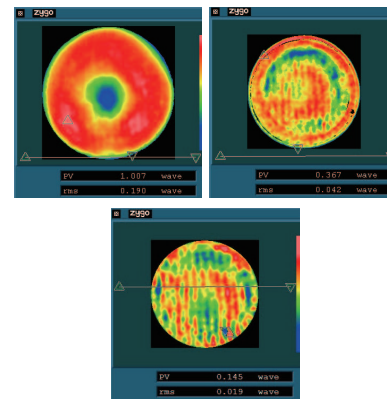


Fig. 5. (Color online) The surface errors during polishing with MMAP.

to decrease the effect of regular polishing ripple, we add some random changes on the tool-path. The tool was moving from inner to outside and made sure the removal ability stable in edge region.

The initial surface error is  $0.19 \lambda$  (root mean square (RMS),  $\lambda=632.8 \text{ nm}$ ). After two step polishing by MMAP, the final surface error is  $0.019 \lambda$  (RMS,  $\lambda=632.8 \text{ nm}$ ) as shown in Fig. 5. The final surface still has a lot of ripples caused by the regular grating path and positioning error. It should be improved in the future research.

In conclusion, the magnetic assistant polishing technology uses the ability of the magnetic powder in designed magnetic field. It is shear removing without pressing, and can be used to finish the thin mirrors. Because of the removal property difference in the edge region, the combination stochastic path is used to decrease the ripple of the fabrication. The initial surface error of the thin mirror work-piece is RMS  $0.19 \lambda$  ( $\lambda=632.8 \text{ nm}$ ), and after twice fabrication, the final surface error is better than  $0.02 \lambda$ . The technology is useful in thin mirror polishing.

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