Ultra-precision Grinding of CVD-SiC Mirrors Using Electrolytic In-Process Dressing(ELID)

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1.Introduction

Large scale reflection mirrors extremely well finished are needed for utilization in the synchrotron radiation facilities. CVD(chemical vapor deposition)-SiC[1] is expected to be an ideal material for the mirrors. CVD-SiC is known as the second best material for mirrors which reflect high energy beams of X-ray and ultra violet ray. This is due to the good heat conductivity and low heat deformation parameter as well as high mechanical strength and fracture toughness. Table 1 shows the properties of typical materials used for the mirrors.

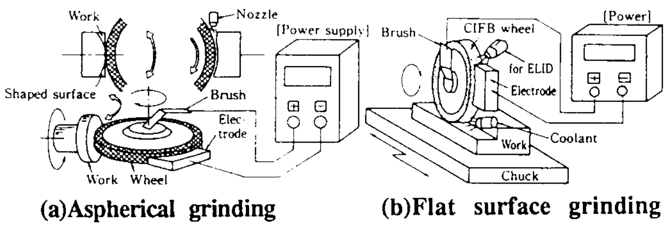
We applied the electrolytic in-process dressing(ELID)[2],[3] to the grinding of CVD-SiC mirrors. This paper describes the performance tests of the ultra-precision ELID-grinding of CVD-SiC mirrors with aspherical and flat surfaces.

Table 1 Properties of typical materials for mirrors

Material	Thermal Conductivity K(W/cm·deg)	Thermal Expansion Coeff. $\alpha (\times 10^{-6}/deg)$	Figures of Merit Deformation $K/\alpha (10^{5} W/cm)$
Diamond	6.0	1.5	40
SiC	2.0	4.3	4.7
Si	0.86	2.4	3.6
Si_3N_4	0.098	2.75	0.36
Mo	1.4	5.1	2.7
Cu	4.0	16.0	2.5
Al	2.4	24.0	1.0
Fused Silica	0.021	0.55	0.39

2.ELID-grinding method

Aspherical CVD-SiC mirrors were ground with ELID on an ultra-precision aspherical generator. Figure 1(a) shows this grinding method by use of the ELID-technique. Metal-bonded grinding wheels, which were thinner at the periphery than the center were used to form both convex and concave shapes. The wheels were numerically controlled.



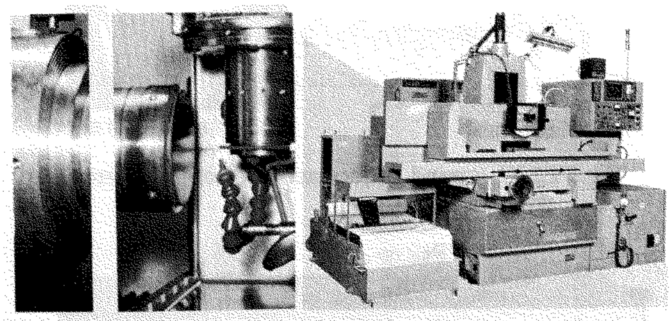
(a)Aspherical grinding (b)Flat surface grinding

Fig.1 ELID-grinding principle for mirrors

Flat CVD-SiC mirrors were ELID-ground on a surface grinder. Figure 1(b) shows the grinding of flat mirrors by use of the ELID-technique. The wheels are straight, flat and of a uniform thickness. Flat surface mirrors can be efficiently finished by contact with the entire width of the wheel in a reciprocating movement across the entire work surface.

3.Experimental setup

The two types of ultra-precision ELID-grinding equipments shown in Figure 2 were employed. An aspherical generator with a feedback resolution of 10nm, air-hydrostatic bearings for spindles, and oil-hydrostatic slide ways was used. A flat surface grinder with a feedback resolution of 100nm, and oil-hydrostatic spindle and slide ways was used. Cast iron bonded (FCI: FUJI ELIDER, Fuji Die Co., Ltd.) diamond wheels of #400, #1000, #4000 were used for aspherical grinding, and #325, #2000, #8000 for flat surface grinding. CVD-SiC workpieces (Pillarbide Crystal, Nippon Pillar Packing Co., Ltd.) with a coating layer of 200μm on a ceramic SiC base of 100mm in diameter and 200mm × 200mm square with thickness of 15mm were ground. Specialized power supplies (ED630: FUJI ELIDER, Fuji Die Co., Ltd.) were adapted for ELID. Optical instruments were used for the evaluation of the surface accuracies of the finished mirrors.



(a)Aspherical grinder (b)Flat surface grinder

Fig.2 Ultraprecision ELID-grinding machines

4.Experimental results

A spherical mirror with a 2m radius of curvature was ELID-ground with #400, #1000, and #4000 wheels. Good surface accuracy of around 0.20μm for 100mm in diameter shown in Figure 3 was achieved.

A parabolic aspherical mirror represented by the formula: $Z=2.62039 \cdot 10^{-4}x^2$ was ground by the same processes. Figure 4 shows the ground surface generated in ductile mode. It took 1.5 hours to finish the aspherical mirror from the #400 to the #4000 process.

A flat surface mirror was ELID-ground with #325, #2000, and #8000 wheels. Good surface finish of several nanometers, as shown in Figure 5(a), was obtained. Figure 5(b) shows the surface flatness after grinding. Very good surface accuracy could be obtained in a reasonable grinding time of around 1.5hours. Figure 6 shows the view of the ELID-ground mirrors. Additional polishing with loose submicron diamond abrasives named "super-polishing" was performed. Figure 7 shows the polished surface accuracy: several angstroms in surface finish and 0.15μm in form accuracy.

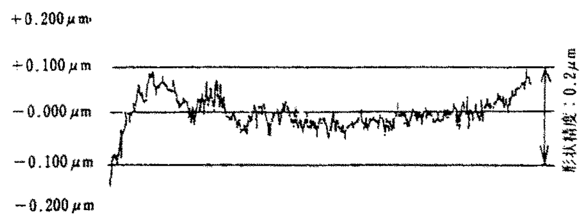


Fig.3 ELID-ground form accuracy

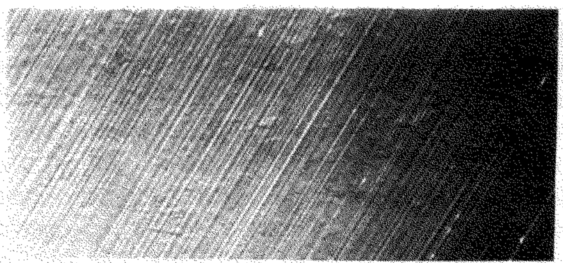
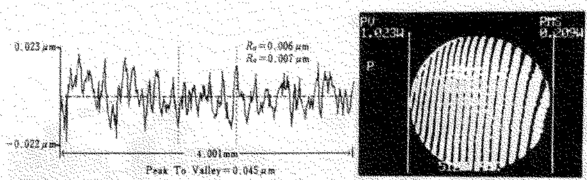
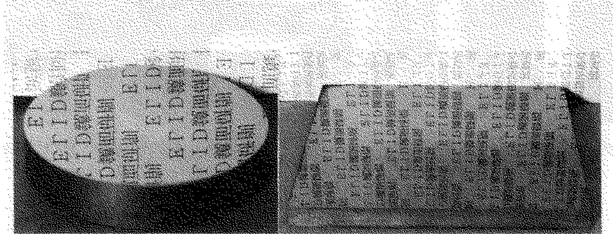


Fig.4 ELID-ground surface quality



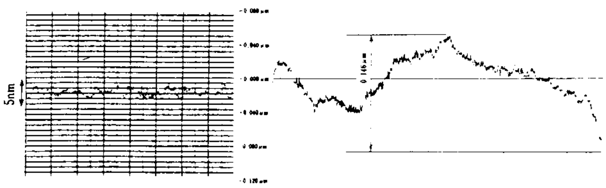
(a)Surface finish (b)Surface accuracy

Fig.5 ELID-ground surface accuracy of flat mirror



(a)Aspherical mirror (b)Flat surface mirror

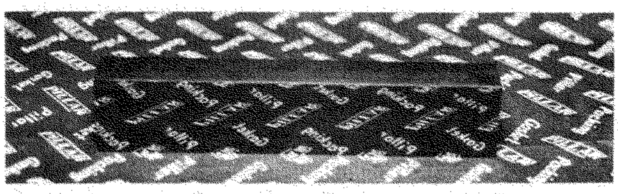
Fig.6 Examples of ELID-ground CVD-SiC mirrors



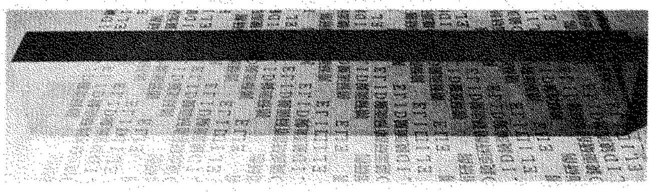
(a)Surface finish (b)Surface accuracy

Fig.7 Surface accuracy after additional polishing

Manufacturing of bending mirrors targeting practical uses was tried through the developed ultra-precision ELID-grinding and the super-polishing technique. Figure 8 shows the finished CVD-SiC mirrors of 150mm and 300mm in length. Monocrystalline silicon mirrors was also finished with ultra-precision surface accuracy through the ELID-grinding technique.



(a)150mm mirror



(b)300mm mirror

Fig.8 Bending mirrors manufactured by using ELID

5.Conclusions

This report has described the performance tests of ultra-precision ELID-grinding of CVD-SiC mirrors. Good surface-quality and shape-accuracy were obtained in reasonable grinding time. Surface accuracy of several angstroms required for practical uses, such as X-ray mirrors was achieved with additional "super-polishing".

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