Ultraprecision Polishing of CVD-SiC Mirrors

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1.Introduction

In order to develop next generation electronic devices with extreme high performances, the "design-rule" in current ULSI patterns should be improved considerably. The current semiconductor exposure technology, however, seems to face a limitation in its principle to cope with such high-tech chip fabrications. One solution to this is applying new sources of exposure rays such as SOR, FEL, and UVUL. Subsequently, ceramic reflective mirrors which have low heat deformation and are precisely polished must be practically available in order to use these new exposure rays.

A smooth surface finish of approximately 0.3nm in RMS is required to reflect SOR rays effectively in the study of molecular biology and micro-machining of semiconductors. Achievement of such surface smoothness was difficult in conventional ceramics because of the crystalline size and/or direction irregularities. In this situation, the authors succeeded in producing reflective mirrors up to 1000mm for SOR rays by applying the CVD-SiC coating technology with high oriented β-SiC(220) face developed in our previous study, and through the combination of the newly developed ultraprecision polishing and measuring techniques described in this paper.

2.Local Polishing Method

2.1 Development of local polishing method

Flat mirrors of 700mm in length for bending are required for these applications. Attempts were made to polish a flat mirror of 300mm in length, and 80mm in width through the development of a local polishing method using a small tool. The target values of the polishing are shown in **Table1**.

Table 1 Target values of polishing

Surface flatness	PV λ/8
Surface roughness	Several angstroms in RMS

PV=Peak to Valley, λ=0.6328 μm, RMS=root-mean-square roughness. 1 Angstrom=10^{-10}m

The developed local polishing using a small tool, the "LPST" method in short, is a controlled polishing method which can generate flat surfaces with high repeatability accurately by concentrating to remove convex local areas using a small polishing tool according to the surface profile measuring data. **Figure 1** shows the principle of this method, and **Figure 2** shows the external view of the experimental polishing machine equipped with this LPST unit. The procedure of the LPST method is performed to the following.

In order to apply this local polishing method to practical mirror finishing, the following have mainly been studied;
1)Development of small tool: Tool with stable polishing rate, and producing smooth surface qualities.

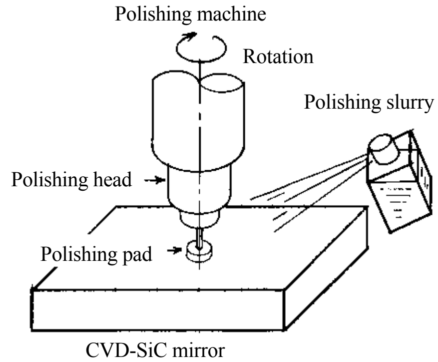


Fig.1 Principle of local polishing method

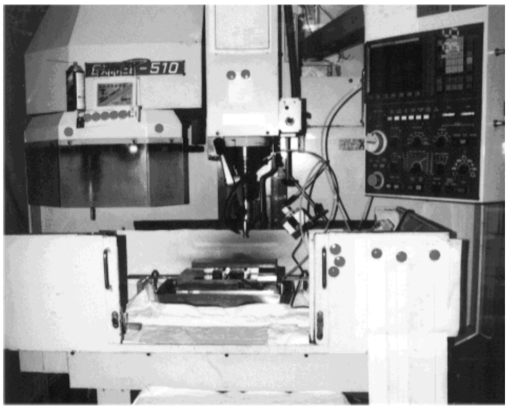


Fig.2 External view of machine used

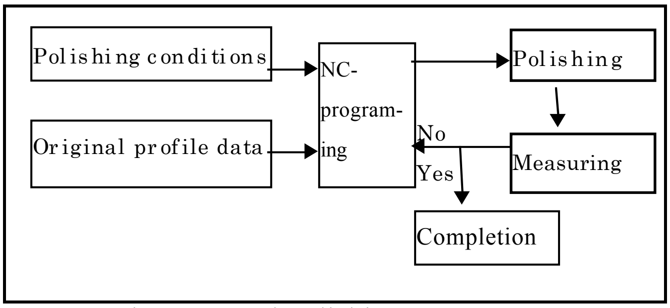


Fig.3 Local polishing processes

2)Development of surface measuring technique: Overlapping analyzing technique of interferometric surface images
3)Development of NC programming system: Data conversion software from analyzed data

2.2 Experimental results

Through the development of the above mentioned techniques for reliable mirror polishing, experimental processes for a CVD-SiC 300L×80W flat mirror were conducted. As a result, the target values of λ/10 in PV flatness, 3 angstroms in RMS for the measured area of 290L×70W were achieved. The surface profile is shown in **Figure 4**, and the surface roughness is shown in **Figure 5**.

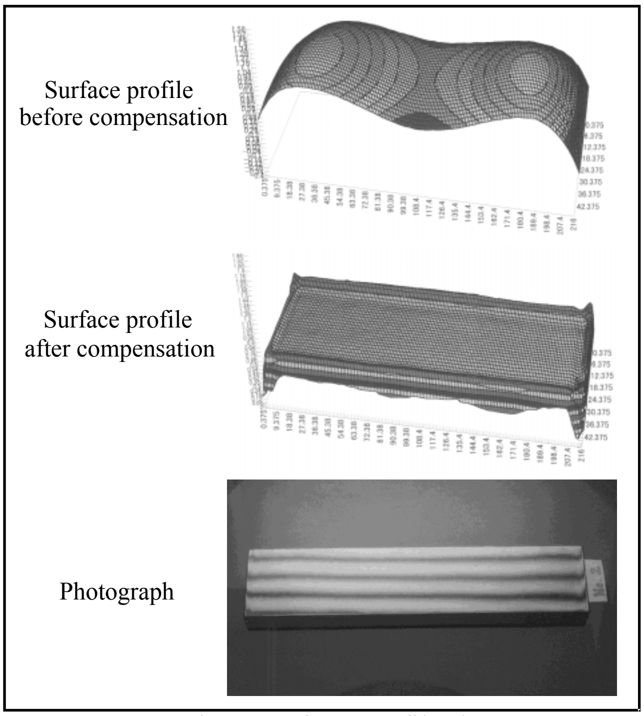


Fig.4 Surface profile data

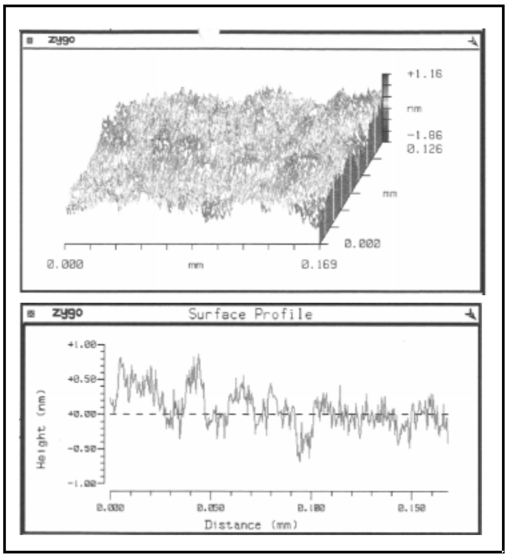


Fig.5 Surface roughness data

2.3 Investigations and discussion

The target values for surface flatness and surface roughness for the evaluated 290L×80W area were achieved to produce CVD-SiC reflective flat mirrors of 300L×80W through the development of the LPST method. Further inprovement of the developed polishing technique to reduce the dulled parts at the edges of the polished mirrors and to reduce small scratches is required.

3. Surface Measurement of Large Flat Mirrors

3.1 Overlapping synthesis of analyzed profile data

A laser interferometer is generally used to evaluate the required profile accuracies of optical elements. However, limits are faced in the evaluation of large mirrors because conventional laser interferometers with small apertures are unable to measure the entire surface of the mirrors.

The developed surface measuring method divides the entire surface area into small areas visible by the conventional interferometer with a small aperture, and generates the entire evaluated surface profile data by overlapping each of the small evaluated data. Thus, large flat mirrors can be evaluated by small interferometer entirely.

The generation procedure is shown in **Figure 6**: The original mirror surface is divided into small areas. Each surface area measured by an interferometer, overlaps by 50% with the next surface area. The inclination of the overlapped surface area is calculated by least squares method.

Next, the first and third surface areas are connected by the second surface area, and the surface inclination data of the overlapped area. Next, the third and fifth surface areas are connected by the fourth surface area and the surface inclination data of the overlapped area. Thus, each odd surface area is connected using each in-between even surface area and the surface inclination data of the overlapped area. Finally, the entire surface profile is synthesized through general compensation of the entire surface inclination connected.

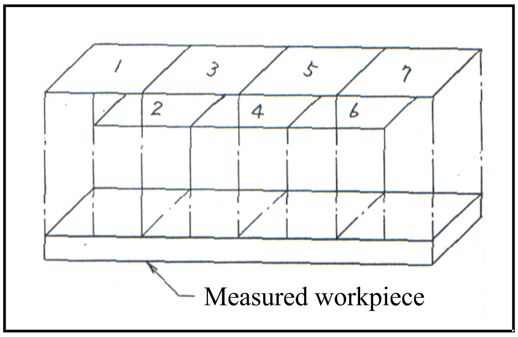


Fig. 6 Measuring procedure

3.2 Investigation of overlapping accuracies of measured surface profile data

To investigate and improve the overlapping accuracy of the measured surface profile data, a large flat mirror of 500mm in length was evaluated by the above mentioned method. The experimental equipments are as follows:

･Workpiece to be measured: 510L×55W bar mirror, material: glass with low heat deformation (original surface flatness: 0.0354 μm in PV for 500L×50W)

･Interferometer: Zygo GPI-XP HR, view area is 6" in diameter (approximately ϕ150mm)

3.3 Measuring conditions

･7 surface synthesis with 6" lens

･Evaluated area: 498L×49.5W (supported by two knife edges as shown in **Figure 7**)

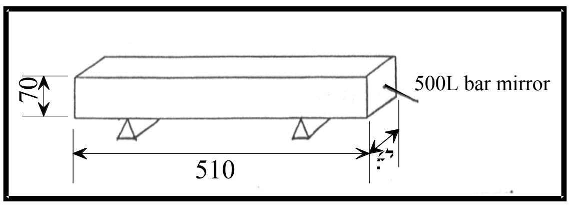


Fig. 7 Supporting method

The experimental procedure is as follows:
1)Measurement of 7 surface area by 6" lens on the interferometer
2)The obtained measuring data is connected and synthesized to evaluate the entire surface profile using the developed specific software.

3.4 Experimental results

The resultant values of the entire surface evaluation are shown in **Table 2**.

Table 2 Results by measurement

No.	Evaluated surface accuracy μm in PV
1	0.0543
2	0.0550
3	0.0462
Average	0.0518

3.5 Investigations and discussion

The entire surface obtained was 0.0518 μm in PV by the method developed for the 500L bar mirror of 0.0354 μm in PV which was originally evaluated using a special large scale interferometer. The evaluation error is small enough (0.0164(λ/38)=0.0518-0.0354 μm) , and the connection error which is visible as the steps in-between the connected area could be reduced through the improvement of the software. However, further improvement of the evaluation accuracy should be considered through the following solutions:
1)Deviation of the evaluated data should be reduced through the consideration of system errors during the evaluation.
2)Environmental influences such as change of room temperature, instability of atmosphere, vibration, etc. should be reduced.

4. Polishing and Measuring Technique of Spherical Mirrors

4.1 Purpose and procedure

A profile measuring technique for spherical mirrors such as R200, R2000, etc. must be developed together with the polishing technique. By comparing the measurements of the spherical glass referential standard and the workpiece to be polished, the LPST method to remove the error was conducted repeatedly. **Figure 8** shows the measuring method used.

4.2 Experimental results

The polishing processes and the conditions are shown in **Figure 9**.

1) R200 spherical mirror (shown in **Figure 10**):
Profile accuracy : 0.151 μm in PV(λ/4)
Surface roughness : 9 angstroms in RMS
2) R2000 spherical mirror (shown in **Figure 11**):
Profile accuracy : 0.212 μm in PV(λ/3)
Surface roughness : 3.3 angstroms in RMS

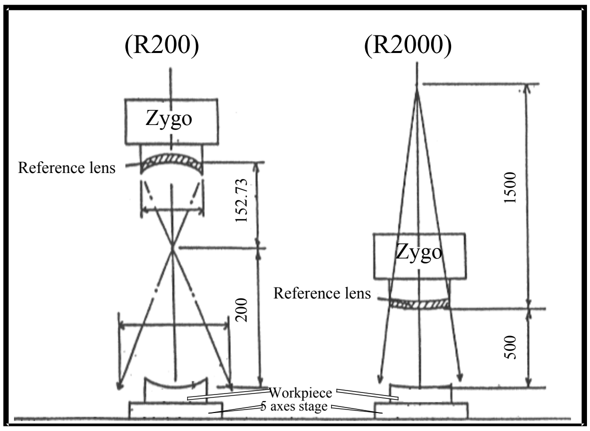
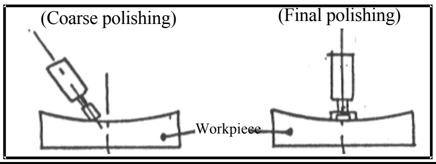


Fig. 8 Measuring method



	Process	Tool dia.	Tool radius	Feed-pitch	Grain size	Polishing profile	accuracy roughness
R 200	coarse	13mm	point	.375mm	1um	PV.6um	RMS44A
	middle	16mm	R200	1.5mm	1um	-	RMS17A
	final	16mm	R200	1.0mm	1/4um	PV.15um	RMS9.0A
R 2000	coarse	13mm	point	.375mm	1um	PV.6um	RMS42A
	middle	16mm	R2000	1.5mm	1um	-	RMS14A
	final	16mm	R2000	1.0mm	1/4um	PV.212um	RMS3.3A

Fig.9 Polishing processes and conditions

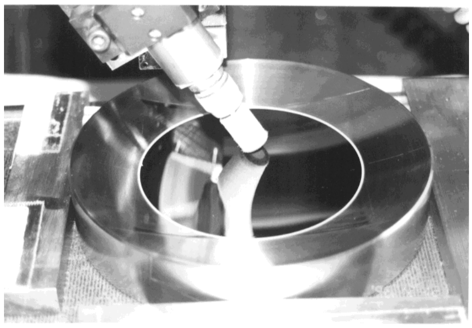


Fig.10 Rough Polishing (R200)

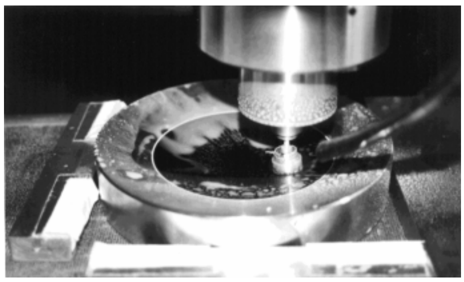


Fig.11 Precision Polishing (R200)

5. Conclusion

Large flat CVD-SiC mirrors could be successfully produced by the developed polishing and measuring method. Spherical mirrors could also be polished. Fabrication techniques of free form curved mirrors including aspheric mirrors must be established for a wide range of future applications. This research and development was supported by the R&D Grant for Creating New Industries of the Hyogo Prefecture.