Characterization of Total Reflection Mirrors Fabricated with Chemical Vaporization Machining (CVM) and Elastic Emission Machining (EEM) Techniques

One of the most irritating problems in X-ray optics for 3rd generation synchrotron radiation has been spatial fringes observed in the totally reflected beam by mirrors. The relatively high spatial coherence of the X-rays from 3rd generation sources makes interference fringes caused by figure errors in mirrors fabricated with conventional polishing techniques. To fabricate higher-quality mirrors with less figure- and slope-errors is a challenge to realize the coherence preserving optics which are required for both 3rd and the coming 4th generation sources.

A group from the Department of Precision Science and Technology of Osaka University and the SPring-8 Optics Group started collaboration on the fabrication of new-generation mirrors in February 2001. X-ray reflection properties are compared by observing the images of the reflected beam at different mirror-detector distances among mirrors fabricated with (i) a conventional polishing technique, (ii) chemical vaporization machining (CVM) [1], and (iii) elastic emission machining (EEM) [2].

A characterization setup was constructed at the one-kilometer experimental station of BL29XU [3], using a standard diffractometer for precision optics [4] as a mirror orientator, and Hamamatsu Zooming Tube as a high spatial-resolution image detector (Fig. 1). A sample mirror prepared from a (001) Si slab was firstly prepared with a conventional polishing technique, a striped region was refined by a CVM technique, and then a part of the CVM-finished striped region was further refined by an EEM technique (Fig. 2)[5].

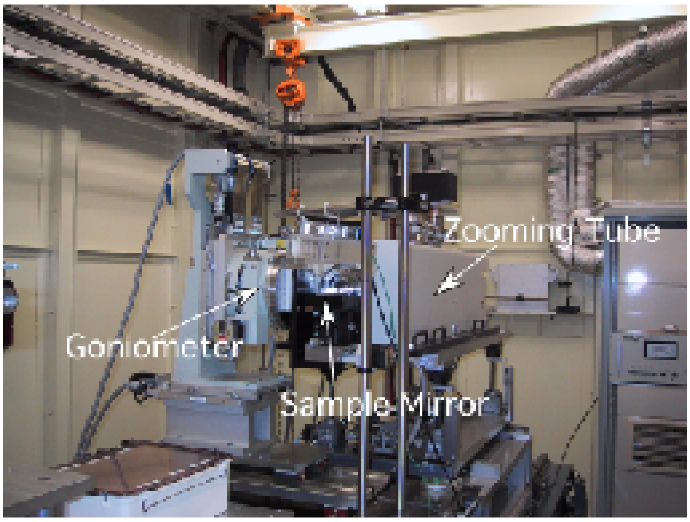

Fig. 1. A mirror characterization setup constructed at the 1-km endstation of BL29XUL.

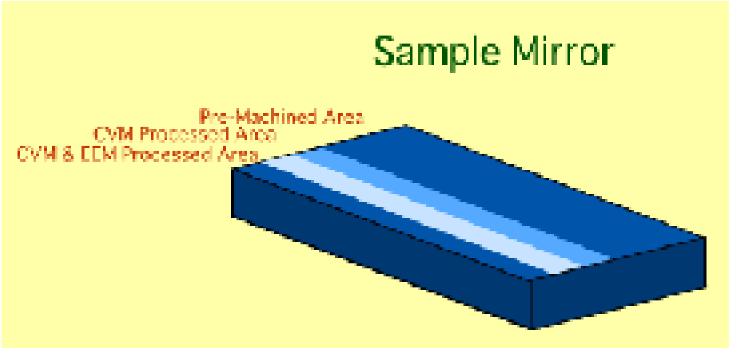

Fig. 2. Sample mirror. A (001) surface of Si (50 mm × 100 mm) was firstly finished with a conventional polishing technique (Pre-Machined Area). A striped area was refined by a CVM technique, and a part of this was further refined by an EEM technique.

In Fig. 3 are shown images of reflected beam from a conventionally polished area (designated as Pre-Machined), a CVM finished area and an EEM-CVM finished area taken at three different sample-detector distances (166 mm, 566 mm, and 966 mm). The surface profiles measured with an optical interferometric technique are also shown. A slight curvature of the conventionally polished region gave rise to a focusing effect, changing the size of the reflected beam with the detector position. High-contrast interference fringes can be observed on the pre-machined surface. CVM correction of the surface profile could remove the curvature, and bring the peak-to-valley height error to within several nm. Nevertheless, the fringe contrast in the reflected beam images still remains. Additional EEM correction of the surface profile reduced the peak-to-valley height error to below 2 nm. The fringe contrast in the reflected beam images faded out for the EEM finished surface, except on the edge region where the edge effect is dominant.

For the correction of surface figure with the EEM technique, an advanced metrology with high accuracy is quite important. We found that the widely used surface profile measurement technique, the Long Trace Profiler (LTP) [6] had insufficient spatial resolution for the fabrication of mirrors suppressing interference fringes. Therefore, stitching interferometry combining the ZYGO NEW-VIEW with large area Fizeau interferometer was developed. The surface profile measured with the new stitching technique reproduced the observed beam profiles fairly well by calculating numerically the Fresnel-Kirchhoff integral for the incident full-spatially-coherent X-rays [5]. An algorithm to retrieve the surface figure from beam images at different sample-detector distances was also successfully developed [7].

Since both CVM and EEM are based on chemical processes which occur in removing atoms from the mirror surface, they do not damage the crystal lattice of the works. Therefore, these techniques are easily applicable to Bragg-diffraction optical elements such as monochromator crystals. A good agreement between the observation and Fresnel-Kirchhof simulation has opened up a new possibility to fabricate figured mirrors for focusing optics with CVM and EEM. A preliminary prototype has already been fabricated, giving a 0.1 µm wide line focus for 15 keV X-rays.

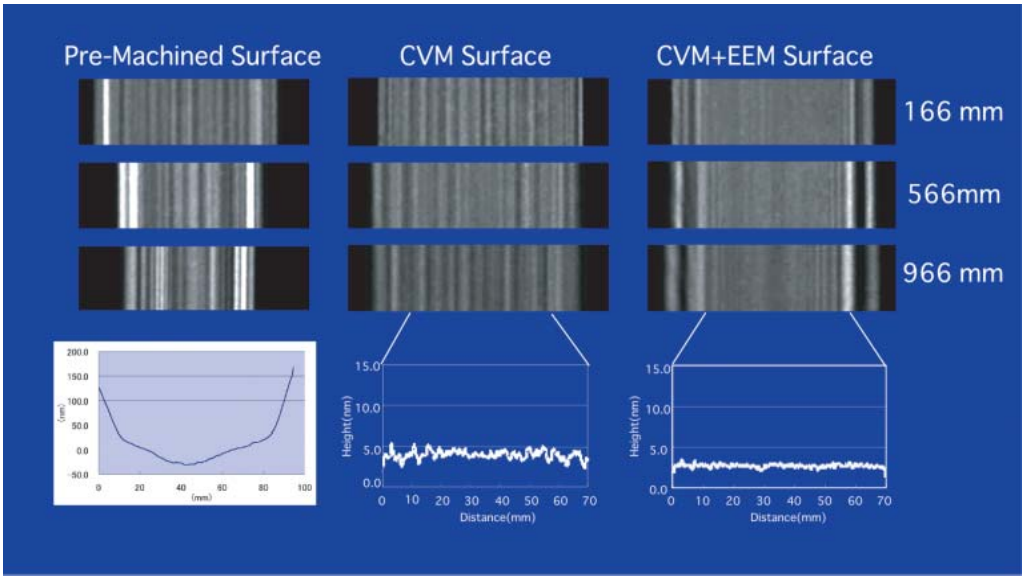

Fig. 3. Images of reflected beams from conventionally polished (designated as Pre-Machined) area, CVM finished area and a CVM+EEM finished area recorded at 166 mm, 566 mm and 966 mm from the center of mirror. Corresponding surface profiles measured with an optical interferometer are shown. Glancing angle of 1.2 mrad at 15 keV X-rays.

References

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