Development and Surface Evaluation of Large SiC X-ray Mirrors for High Brilliance Synchrotron Radiation

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Recent synchrotron radiation (SR) sources such as undulator and wiggler give large heat load for the beamline optics. In the SPring-8 the total power of typical insertion devices is estimated as about 18 kW for a wiggler and 5 kW for an undulator. When the mirror is used as a first optics to reflect the white beam it has to withstand the absorbed power ranging from a few hundreds W to a few kW from those insertion devices. A lot of mirror substrate materials have been used. The mirror material should be chosen from view points of thermal characteristics, technical problem to get surface finish of the order of a few A and vacuum compatibility at high brilliance synchrotron radiation beamlines. As results of preliminary heat load tests, SiC has been widely used. In the SPring-8 if the first mirror is set out of the shield wall to access easily, the distance from source point to the mirror is more than about 35 m. The photon beam divergence requires the flat mirror length of the order of 1 m at the position. For wiggler beamline much longer mirror is necessary if cylindrical mirror is used. Larger size of the mirror as much as possible is desirable since the composition of small mirrors require precise control and normally it becomes difficult to get the reflected beam with good quality. Surface roughness is one of important characteristics for x-ray mirror since it directly affects on the reflectivity. It is desirable to polish the mirror surface to the roughness of less than a few A throughout a whole area. Generally the surface roughness is measured by using heterodyne laser interferometers, which can give local surface finish. But it is difficult to measure the surface roughness as a function of surface position throughout whole surface area for large mirror. On the other hand, large scale surface figure of the mirror has been measured by the long-trace surface profiler and the large surface profiler with laser. X-ray scattering measurements are, however, indispensable and the best way for the final qualification for x-ray mirror surface and for the feedback to suppliers. For small mirrors, some experiments to characterize the surface had been performed by x-ray and focus the study on the surface roughness. For larger mirror, x-ray characterization is rare. In this study the surfaces of the mirrors are studied by measuring the reflectivity and evaluating the surface roughness as a function of mirror surface position, and the surface figure, without heat load by using x rays as well as laser interferometers. One of the physical interests is to study surface finish from a view point of *fractal* structure for large mirror which was confirmed for artificially-polished small sample mirrors. Advantages to measure the scattering profiles as angle resolved scattering (ARS) curves are to give the power spectra as a function of surface wave number. The order of the longitudinal curvature can be estimated from the x-ray measurement of the reflected beam profile at small glancing angle.

According to above requirements, large SiC mirrors coated with Pt, 800 mm and 1000 mm long, have been developed for the use of high brilliance synchrotron radiation beamline under the cooperation with the suppliers, Nikon and Canon[1-4]. Large mirrors are evaluated by the measurements of not only the reflectivity, but also the power spectra which are derived from the ARS curves[5]. The x-ray experiments are performed with the collimated x-ray beam of 1.54 A by utilizing the evacuated 30 m long beamline facility[6]. The reflectivity and the power spectrum density (the surface roughness) are measured two-dimensionally as a function of mirror surface position. Figure 1 shows the reflectivity map on the mirror surface at the glancing angle of 0.5° for the 800 mm long mirror. The mapping of the reflectivity measurements performed at near the critical angle gives differences of the surface roughness clearly since the reflectivity becomes sensitive at near the critical angle. The raw data of ARS curves at several glancing angles are shown in Fig. 2 together with the incident (direct) beam profile for 800 mm long mirror. Strong asymmetric tails which are related with Yoneda and anti-Yoneda peaks are observed. In Fig. 3 the power spectrum densities derived analytically from ARS curve measurements are indicated. Analytical results of the ARS curves suggest the possibility that the artificially-polished mirror surface may have *fractal* structure like small sample mirrors. In the power spectra of Fig. 3 the fractal dimension ranges from 2.7 to 3.0. Figure 4 shows map of the RMS surface roughness derived from ARS curves at the glancing angle of 0.5° for 800 mm long mirror. We can observe strong correlation with the results in Fig. 1.

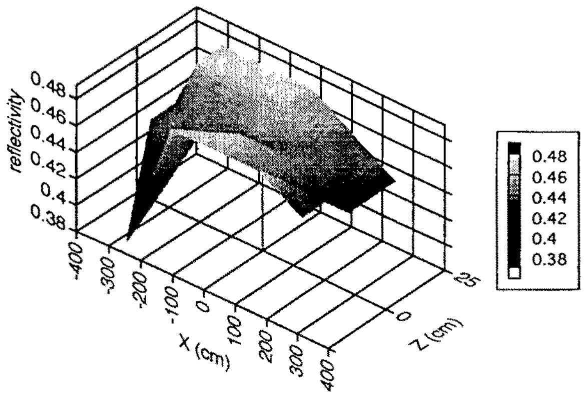

Fig. 1 Two-dimensional mapping of the reflectivity on the mirror surface at the glancing angle of 0.5° for the 800 mm long SiC mirror.

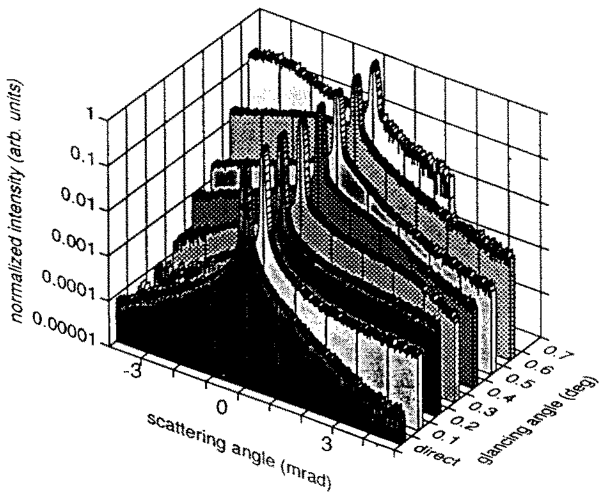

Fig. 2 Comparison of the angle resolved scattering (ARS) curves as a function of glancing angle with direct beam at the mirror center position of 800 mm mirror.

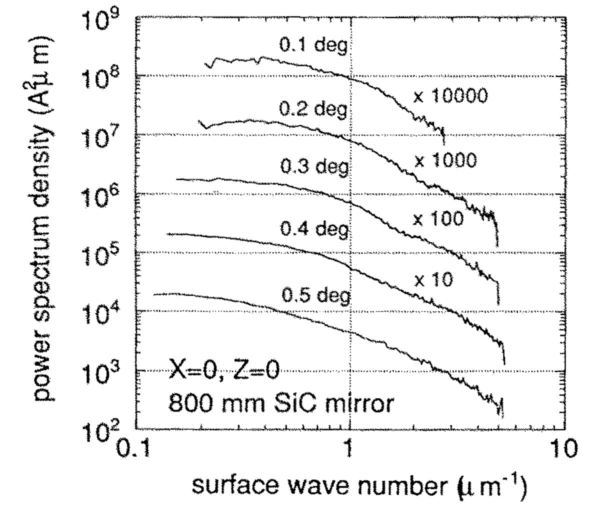

Fig. 3 The power spectrum density for each glancing angle as a function of surface wave number at the center of the mirror derived analytically from the ARS curve.

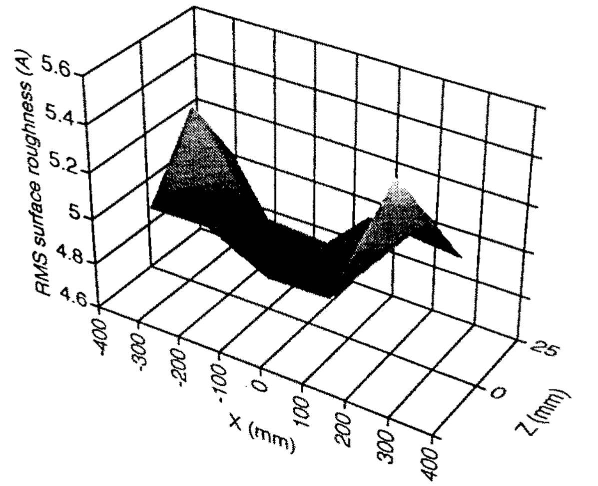

Fig. 4 Two-dimensional mapping of the RMS surface roughness at the glancing angle of 0.5° for the 800 mm long mirror.

The surface figure as mirror curvature of the order of 10 km is also evaluated for the 800 mm long mirror by utilizing the difference of the reflected beam profiles between the widths of incident beam and the reflected beam. The x-ray measurements are compared with the those of laser interferometers and agree qualitatively.

We would conclude from those measurements for the 800 mm SiC mirror that the mirror surface is well polished uniformly enough to use in the SR beamline. Similar measurements for the 1000 mm long mirror gave good performance as well.

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