Experimental Facilities Division
Optics Fabrication and Metrology

FROM FLAT SUBSTRATE TO ELLIPTICAL K-B MIRROR BY PROFILE COATING

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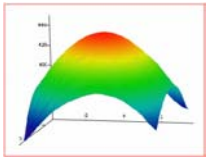
Abstract

For microfocusing x-ray mirrors, an elliptical shape is essential for aberration-free optics. However, it is difficult to polish elliptical mirrors to x-ray-quality smoothness. Profile coatings have been applied on both cylindrical and flat Si substrates to make the desired elliptical shape. In a profile-coating process, the sputter source power is kept constant, while the substrate is passed over a contoured mask at a constant speed to obtain a desired profile along the direction perpendicular to the substrate-moving direction. The shape of the contour was derived from a desired profile and the thickness distribution of the coating material at the substrate level. The thickness distribution was measured on films coated on Si wafers using a spectroscopic ellipsometer with computer-controlled X-Y translation stages. The mirror coating profile is determined from the difference between the ideal surface figure of a focusing ellipse and the surface figure obtained from a long trace profiler measurement on the substrate. The number of passes and the moving speed of the substrate are determined according to the required thickness and the growth-rate calibration of a test run. A K-B mirror pair was made using Au as a coating material and cylindrically polished mirrors as substrates. Synchrotron x-ray results using this K-B mirror pair showed a focused spot size of 0.4 x 0.4 mm^2. This technique has also been applied for making elliptical K-B mirrors from flat, commercially available Si substrates. Test mirrors with 60 and 120 mm focal lengths have been successfully fabricated. It has been demonstrated the it is possible to use a single mask to make multiple elliptical K-B mirrors (with the same design parameters) for synchrotron undulator beamlines.

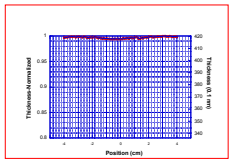
Profile Coating

Au thickness distribution:



Contoured mask
+
Substrate moving

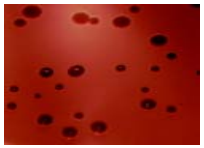
Uniform coating (<0.3%):



Challenges for K-B on flat Si

Problems

The film became droplets:
Au/Si, ~1 nm to ~4 μm across 25 mm.
Droplets: ~5-50 μm wide 0.5-4 μm high.



Solutions

1. Increase the Cr glue-layer from 5 nm to 10 nm.
2. Coat a uniform Au buffer layer, ~50 nm thick.
3. Add 50 nm Au everywhere in the profile.
4. Build up the Au gradient gradually, with a 15 minute break between every ~1 μm of Au coating at the thickest end of the profile.

Results

No droplets visible:
Au, ~50 nm to ~4 μm across 25 mm,
on top of 50 nm Au on 10 nm Cr on Si.

Small Deposition System

Capable of coating optics having dimensions of up to 10 cm x 22 cm x 2.5 cm

2 Sputtering guns, using 3" dia. Targets

DekTak 8 Stylus Profiler | **M-44 Ellipsometer**

Kirkpatrick-Baez (K-B) mirrors

Two mirrors at glancing angles to the x-ray beam and arranged 90° to each other to successively focus x-rays in the vertical and horizontal directions.

Elliptical K-B mirrors

Aberration free, non-dispersive focusing.

Monolithic K-B mirrors

Ease of use.
Small mirror-focus distance.

Flat substrates to elliptical K-B mirrors

Very smooth and flat substrates are easy to obtain.
Excellent repeatability of surface quality of flat substrates.

Profile coating makes sense

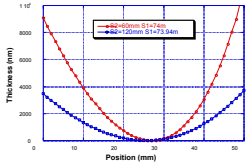
Elliptical mirrors can be fabricated from flat substrates very economically.

Elliptical K-B mirrors for the APS 2-ID beamline

Design Parameters:

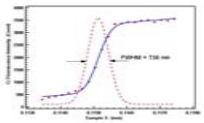
Dimension: 12.5x50x2.5 mm^3.
Mirror 1: S1=74 m S2=120 mm.
Mirror 2: S1=73.94 m S2=60 mm.
Mirror angle: ~3 mrad.

Coating profiles:



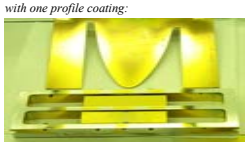
LTP results for the S2=120 mm mirror after two profile coatings:

X-ray result for the S2=60 mm mirror:

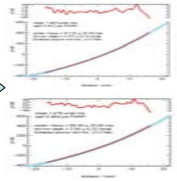


Horizontal resolution test, 10 keV, Cr knife edge scan, solid line: fit of the fluorescence profile (dots), dashed line: derivative of the fitted line.

Two S2=60 mm mirrors coated side by side with one profile coating:



Results for the S2=60 mm mirror after one profile coating:



Summary

Profile coatings have been successfully applied to convert flat, commercially available Si substrates into elliptical K-B mirrors. Test mirrors of 60 and 120 mm focus lengths have been fabricated. It is also possible to use a single mask to make multiple elliptical K-B mirrors with the same design parameters for synchrotron undulator beamlines.

Acknowledgments

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