Thin-Film Depositions for Mirrors & Multilayers

Contact: Chian Liu, *Deposition Captain*
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Large Sputtering System

Physical size limits

Coats substrates up to: 1.5 m long
15 cm wide
14 cm high

Small Sputtering System

Physical size limits

Coats substrates up to: 22 cm long
10 cm wide
2.5 cm high

Ellipsometer

Physical size limits

Sample size: up to 10 cm × 10 cm
Resolution: ~ 1 nm

X-ray Reflectometer

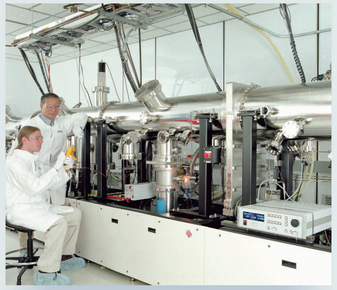
Physical limits

Samples up to 2.5 × 10 × 5 mm^3
Resolution: ~ 0.1 nm layer spacing

Stylus Profiler

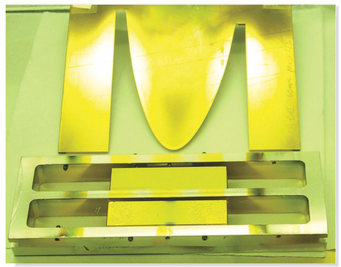
Physical limits

Sample size: up to 20 cm
Scan length: 50 micron to 100 mm
Resolution: ~ 1 nm vertical



Chian Liu (standing) and Ray Conley with the large deposition chamber.

Two substrates ready for coating. The sputtering mask is designed for a profile coating to convert flat substrates into elliptical Kirkpatrick-Baez mirrors. See: "Profile coatings and their applications," C. Liu, R. Conley, L. Assoufid, A. T. Macrander, G. E. Ice, J. Z. Tischler, and K. Zhang, J. Vac. Sci. Technol. A **21**(4), 1579, 2003. v



X-ray Topography & Characterization

Contact: S. (Felix) Krasnicki, *Topography Captain*
krasnick@aps.anl.gov

Topography Test Unit

High-resolution, double-crystal diffractometer
Sample size typically up to 4 in. diameter
Monochromatic beam up to 3 in. × 3 in. footprint

Triple-axis diffractometer

Equipped with 4-circle goniometer for sample size of ~ 5 × 5 × 5 mm
High-resolution reflectivity measurements on samples up to 100 × 50 × 10 mm

Laue Orientation System

Backscattering camera for small samples and up to 4 in.-diameter ingots

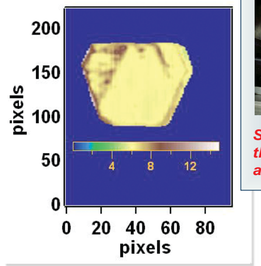
Double-crystal Diffractometer

2 × 2 mm beam, precision sample theta rotation

Crystal Orienter

Single-crystal diffractometer
Sample size up to 4 in. diameter and several in. length

S. Felix Krasnicki (left and Jozef Maj at the topographic diffractometer located at the rotating anode generator.



^ Diamond rocking-curve FWHM map after etching. The color scale is in arcsec. The man-made diamond is type IIa. The sides are 5 × 6 mm long. The FWHM improvement was 0.7 arcsec. See: "Etching of diamonds for x-ray monochromators" by J.A . Maj, A.T. Macrander, S.F. Krasnicki, P.B. Fernandez, R.A. Erck, Rev. Sci. Instrum. **73**, 1546 (2002).

The Optics Fabrication & Metrology (OFM) Group ...

...of the Experimental Facilities Division at the Advanced Photon Source has as its primary mission the characterization or fabrication of x-ray optics to be used at APS beamlines.

Users of the APS and/or resident beamline staff are invited to fill out work requests. The services are provided cost free (with the exception of work that may be requested from Argonne Central Shops as part of the job) to users of the APS and/or resident beamline staff. Central Shops services may include (but are not limited to) grinding and polishing.

The OFM group has silicon, germanium, and quartz raw materials that can be used for fabrication of x-ray optics on a cost recovery basis. Information on filling out work requests can be found at http://www.aps.anl.gov/xfd/optics.

Peter Eng (left, GeoSoilEnviroCARS) and Albert Macrander (OFM Group Leader) outside the X-ray Optics Metrology Lab in the APS experiment hall.

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Optics Fabrication & Metrology

at the

Advanced Photon Source

Metrology of x-ray mirrors & mirror benders

Fabrication of monochromators & analyzer crystals

Thin-film depositions for mirrors & multilayers

X-ray topography & characterization

X-ray optical system design & development

Experimental Facilities Division
Argonne National Laboratory

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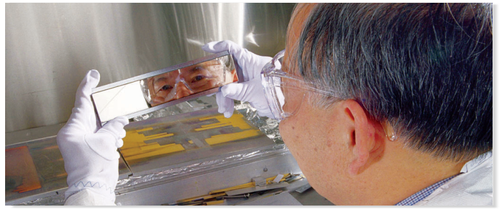
Visit the OFM Group web site at:
http://www.aps.anl.gov/xfd/optics/welcome.html



Clip & Save

X-ray Optical System Design & Development

Contact: Ali Khounsary, *Mirror Design Captain*
amk@aps.anl.gov

Design and Analysis of Optical Systems

Cooled x-ray mirrors, multilayers, and monochromator design; cryogenic and water-cooled optics, deformable optics, slits and windows

Optical Substrate Fabrication

Collaboration on specialized and developmental techniques in optics manufacturing

Test and Evaluation

Computational and experimental study of optical substrates (thermal, structural, optical), thermal contact resistance, and optical ray tracing

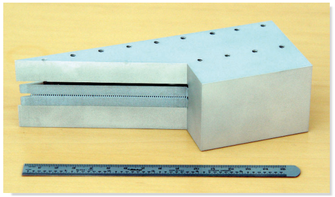
Novel User Optics

X-ray lenses, crystal (Si, Ge, Diamond) monochromators, and nanofocusing Kirkpatrick-Baez optics

Mirror Services

Clean room for mirror assembly, optics cleaning, and etching of coatings

Ali Khounsary (right), with graduate students Kristina Young and Yaming Li with the x-ray reflectometer for multilayer reflectivity measurements.



> X-ray lens based on the principle of refraction. See: "Fabrication, testing, and performance of a variable-focus x-ray compound lens," A.M. Khounsary, S.D. Shastri, A. Mashayekhi, A.T. Macrander, R.K. Smither, and F.F. Kraft, SPIE Conf. Proc. **4783**, 49 (2002).

Metrology of X-ray Mirrors & Mirror Benders

Contact: Lahsen Assoufid, *Metrology Captain*
assoufid@aps.anl.gov

Long Trace Profiler

Scan range: Up to 2 m
Sampling distance: 1 mm
Noise level: < 0.3 µrad rms*
Repeatability: 0.5 µrad rms**
Measurable slope range: ± 5 mrad
Height accuracy: < $\lambda/100_{HeNe}$
Radius of curvature accuracy: <± 5%

Lahsen Assoufid (standing) and Jun Qian with the Long Trace Profiler.

Fizeau Interferometer

Field of view: Diameter: 150 mm, with 6× zoom capability
RMS repeatability: < $\lambda/8{,}000_{HeNe}$
P-V repeatability: < $\lambda/1{,}000_{HeNe}$
Lateral resolution: 0.6-0.1 mm, depending on zoom

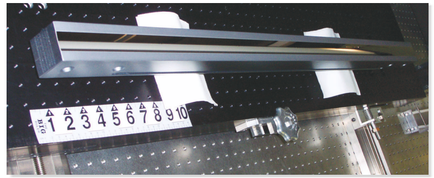
Roughness Interferometer

Field of view: 0.33 mm^2 (Obj. 40×), 2.66 mm^2 (Obj. 5×), 8.87 mm^2 (Obj. 1.5×)
Height resolution: 1 Å rms for 1-D profile, 3 Å rms for 3-D profile
Repeatability: < 1 Å
Measurable height range: Up to 40 µm
Max. measurable step height: Up to 15 µm
Optical resolution: 0.65 µm, 3.97 µm, and 10.83 µm
Lateral sampling distance: 0.325 µm, 2.60 µm, and 8.67 µm

Atomic Force Microscope

Field of view: Up to 130 × 130 μm^2
Vertical range: Up to 12 µm
Vertical resolution: < 1 Å
Lateral resolution: Depends on surface features to be measured and probe-tip characteristics.
Pixel resolution: Up to 500 × 500 pixels

**Standard deviation in the mean profile resulting from averaging ten scans.*
***Obtained by subtracting two consecutive measurement profiles and calculating the rms value of the difference.*



< Mirror mounted for figure measurement on the Long Trace Profiler. **See:** "Improvements in the accuracy and the repeatability of long trace profiler measurements," by P.Z. Takacs, E.L. Church, C. Bresloff, and L. Assoufid, Appl. Optics. **38**, 5468 (1999).

Fabrication of Monochromator & Analyzer Crystals

Contact: Ruben Khachatryan, *Fabrication Captain*
khachat@aps.anl.gov

Meyer/Burger TS-121 CNC Saw

Table limits: X-500 mm,Y-320 mm, Z-160 mm
Maximum size of ingot that can be cut: 5 in. × 5 in. × 10 in.
Diamond blade: 4 in.-16 in. diameter
Kerf width: 0.5 mm-2.5 mm
Crystals that can be cut: Silicon, germanium, quartz, sapphire

Dicing Saw

Substrate dimension: 5 mm thick and up to 250 mm in diameter
Minimum kerf width: 75 µm

Polishers

Maximum diameter substrates that can be polished: 6 in.

Wet Chemical Etching

Si and Ge: HF + HNO_3
Au thin films: aqua regia
Cr thin films: commercially available premixed etch

Other/PFS Optics Shop

Surface grinders, core drill, ultrasound mill, cylindrical grinder

Ruben Khachatryan preparing silicon for cutting on the Meyer/Burger saw.

Cryogenically cooled silicon monochromator. See: "Performance of a liquid-nitrogen-cooled thin silicon crystal monochromator on a high-power, focused wiggler synchrotron beam," C.S Rogers, D.M. Mills, W.-K. Lee, G.S. Knapp, J. Holmberg, A. Freund, M. Wulff, M. Rossat, M. Hanfland, and H. Yamaoka, Rev. Sci. Instrumen. **66**, 3494 (1995) v