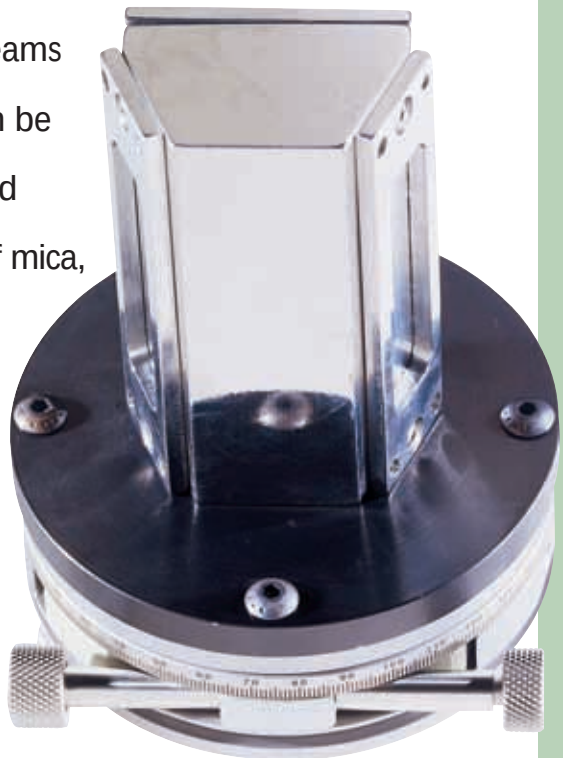
X-RAY OPTICAL SYSTEMS INC.

Monochromatic X-Ray Analysis

Doubly Curved Crystals

Highly monochromatic x-ray beams focused in three dimensions can be obtained by using doubly curved single crystals (DCCs). Crystals of mica, graphite, Si, Ge, and others are used for an x-ray energy range of ~1.5 to 22keV. Crystal optics reflect x-rays based on Bragg diffraction. The DCC accurately images micron-sized as well as large x-ray point sources.



FEATURES:

- 3-Dimensional point-to-point focusing of x rays
- Highly monochromatic beam
- Large capture angle
- High flux-density gain
- High angular uniformity of beam

BENEFITS:

- Extremely low background
- High detection sensitivity
- Detection limits in the ppb range
- Large working distance
- Rapid data collection
- Applications in MMXRF, XRR, and TXRF

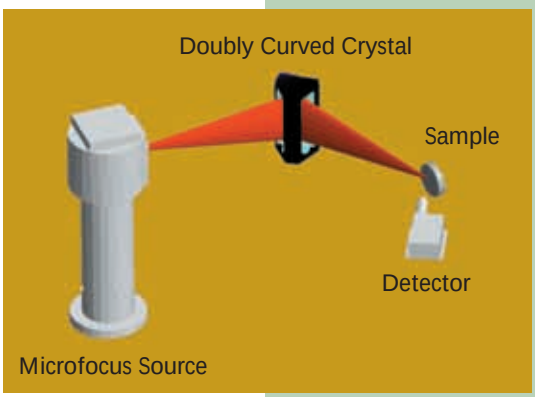
TYPICAL FLUX AND SPOT SIZES

High-power rotating-anode sources:

- **Flux:** $1x10^{11}$ photons per second at the spot
- **Spot size:** ~300 µm x 200 µm

Microfocus sources:

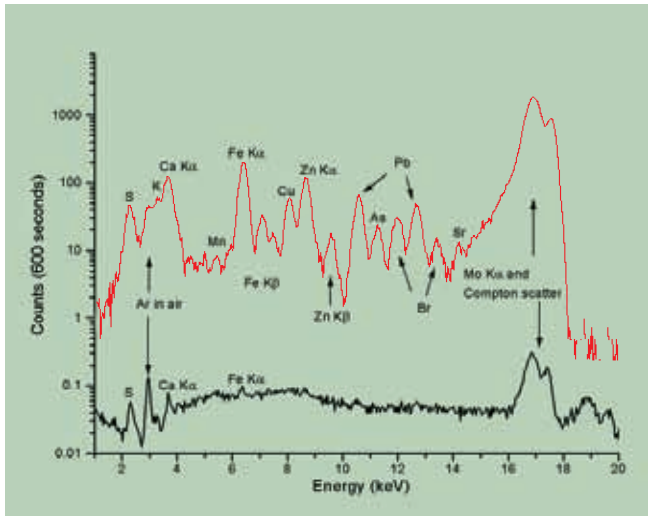
- **Flux:** $1x10^{9}$ photons per second at the spot
- **Spot size:** from 20 µm up to 150 µm (equivalent to source size)



MONOCHROMATIC MICRO X-RAY FLUORESCENCE ANALYSIS (MMXRF)

FIGURE 1
Comparison of a Mo DCC and a pinhole for elemental analysis of concentrated air particulates. Mo excitation (40kV, 20W, 600s)

The detection sensitivity provided by the DCC is greatly enhanced relative to a pinhole. The intensity of the pinhole spectrum was scaled from a 2 mm diameter aperture to a diameter equivalent to 50 μm. The pinhole and the DCC focal spot was located the same distance from the source (120 mm). A PIN detector with a 25 mm^2 active area was positioned 15 mm from the sample to collect both spectra.



MMXRF measurements below were done with an intense, monochromatic, focused beam, a Si(Li) detector, and a microfocus x-ray source (30kV, 3W). Results for high purity Ca and Ti specimens are shown in Table 1; results for mica are shown in Figure 2.

TABLE 1
Signal-to-background ratios for Ca and Ti samples Cu Kα excitation (30kV, 3W, 500s).

Element	Signal*	Background*	S/B
Ca	1.8×10^7	140	1.3×10^5
Ti	3×10^7	200	1.5×10^5

** Signal and background counts are integrated in 10 channels (20eV/channel)*

The signal-to-background ratios for Ca and Ti measurements are more than two orders of magnitude higher than those provided by standard XRF techniques.

FIGURE 2
Fluorescence spectrum of a mica sample using Cu Kα excitation (30kV, 3W, 500s).

Concentrations at the low ppm level were detected in 500s with the source operated at only 3W. Under these conditions the primary beam still delivered a total of ~6×10^7 photons.

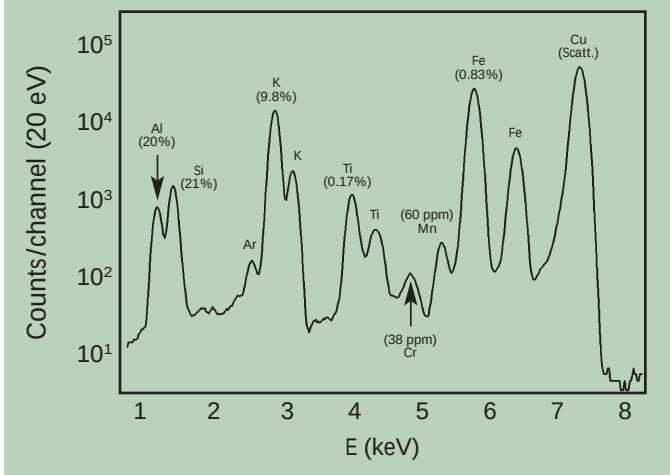
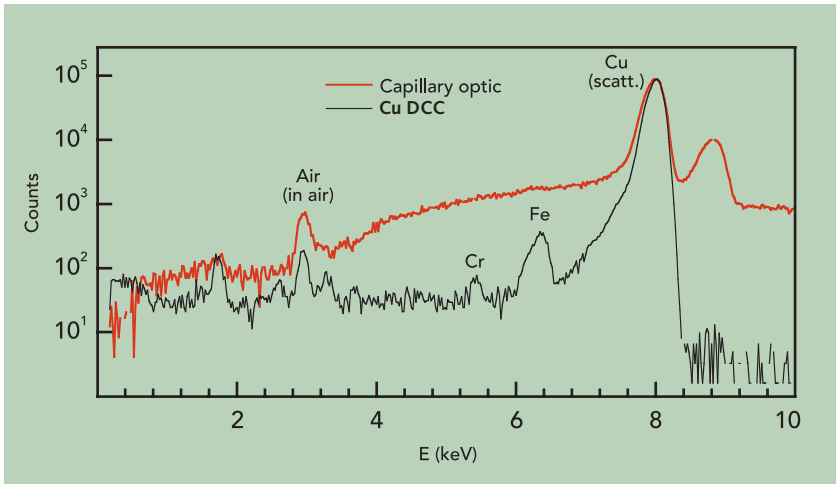


FIGURE 3

Comparison of spectra from a polycapillary optic and Cu DCC, both with 50μm focal spot size.

Si DCC–30kV, 20W, 400s
Polycapillary optic–20kV, 20W, 120s.

Spectra collected from a Lucite® plastic disk. The data shows the background suppression benefit of using DCC optics.



Low background and low detection-limits can be achieved with doubly curved crystals.

TABLE 2

Examples of different DCCs integrated with microfocus x-ray sources:

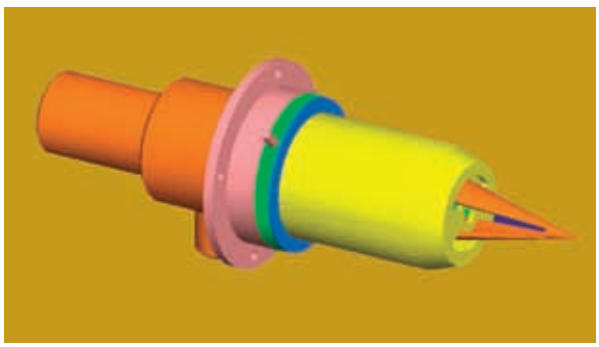
Optic	Energy (keV)	Source Power (W)	θ Bragg	Capture Angle (sr)	Nominal focal spot size, FWHM (μm)	Flux (cps)	Working Distance (mm)
Cr1	5.4	14	35.1	0.03	80	2×10^9	120
Cu1	8.0	14	14.2	0.015	50	1×10^9	150
Cu2	8.0	50	14.2	0.01	150	2×10^9	150
Cu3	8.0	14	22.8	0.01	50	3×10^8	135
W1	8.4	10	22.6	0.01	20	1×10^8	80
Mo1	17.5	14	10.6	0.01	60	1×10^8	120

MONOCHROMATIC CONVERGENT X-BEAM®

For x-ray analysis requiring high flux-density gain and micron-sized x-ray focal spots, XOS® offers DCC optics integrated with microfocus x-ray sources. For example, we offer the following nominal specification:

Flux (Mo Kα): 3.0×10^8 cps at 50 W
Spot (FWHM): 200 μm

Please contact the sales department for information.

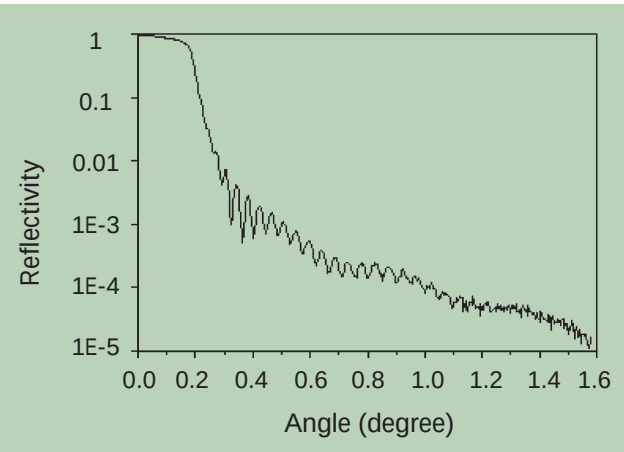


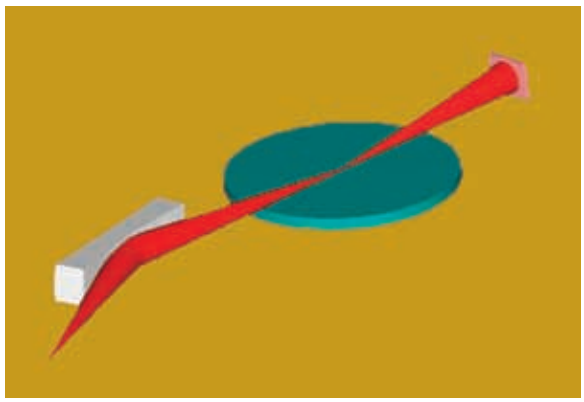
Thin Film/Surface Analysis

X-RAY REFLECTOMETRY (XRR)

XRR data for 800Å TiN film on Si wafer using Tungsten Lα line

- 3.5W (35kV, 0.1mA) source setting; 100s data collection
- The data was collected using a PSD by scanning a 65μm slit positioned 400 mm from the sample. A remarkable angular resolution of ~0.01° and very high count rate was generated using a low-power Tungsten x-ray source with a 40μm spot size.



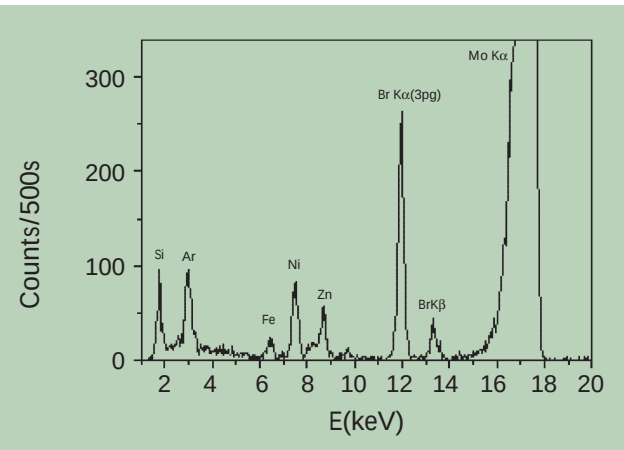


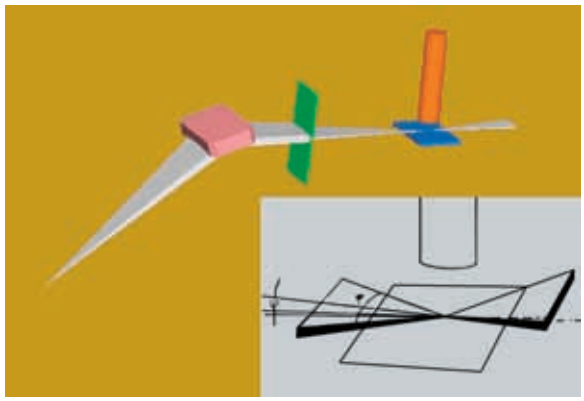
Schematic diagram of XRR geometry.

TOTAL REFLECTION X-RAY FLUORESCENCE (TXRF)

Spectrum of a residue on the surface of a silicon wafer, showing 3pg Br detection using Mo Kα excitation

- 40W (40kV, 1mA) source setting; 500s data collection
- The plot shows a low femto-gram detection limit of about $2x10^8$ atoms with a compact, low-power x-ray source. A small beam size of 100μm is achieved using a Si Doubly Curved Crystal for particle analysis and mapping.





Schematic diagram of TXRF geometry.

X-RAY OPTICAL SYSTEMS INC.

The World Leader in X-Ray Optics and Beams

XOS® offers standard and custom designs for your analytical needs.

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