

Soft X-ray Monochromators

OVERVIEW

Soft x-rays span the region between x-ray and UV, with energies from approximately 10 to 100 Å (0.12 – 1.2 keV). This range of energies is particularly interesting for x-ray spectroscopy. Important applications include x-ray astronomy and metrology of high-energy plasmas (for example, spectroscopy and imaging with x-rays provides information on the composition and behavior of plasmas as a function of time and position). Soft x-rays also have potential use in next-generation surface inspection and material characterization tools. In these applications, the critical optical element is a high quality crystal with suitable interplanar spacing to permit diffraction and focusing of soft x-rays. Inrad Optics offers several crystals suitable for soft x-ray applications, including KAP and RbAP. These crystals can be supplied either flat or bent to a prescribed radius of curvature.

SOFT X-RAY CRYSTAL OPTICS

The periodic atomic alignment characteristic of crystals makes them well-suited for focusing and analyzing x-ray emissions. In large part, the resolution of an x-ray imaging spectroscopy system is determined by the properties and quality of the x-ray diffracting crystal. These crystal optics diffract only x-rays satisfying the Bragg condition, $n\lambda = 2d \sin\theta$, where n is an integer, λ is the wavelength, d is the spacing between adjacent crystal lattice planes, and θ is the Bragg angle.

Crystals of the acid phthalate family offer the wide interplanar spacing required for diffracting soft x-rays and permit spectroscopy and imaging from 2.3 to 25 Å (first order reflection). The acid phthalates have an additional benefit of being easily cleaved to yield thin flat sheets with the desired orientation for diffraction. Two commonly used soft x-ray crystals are KAP (potassium acid phthalate) and RbAP (rubidium acid phthalate).

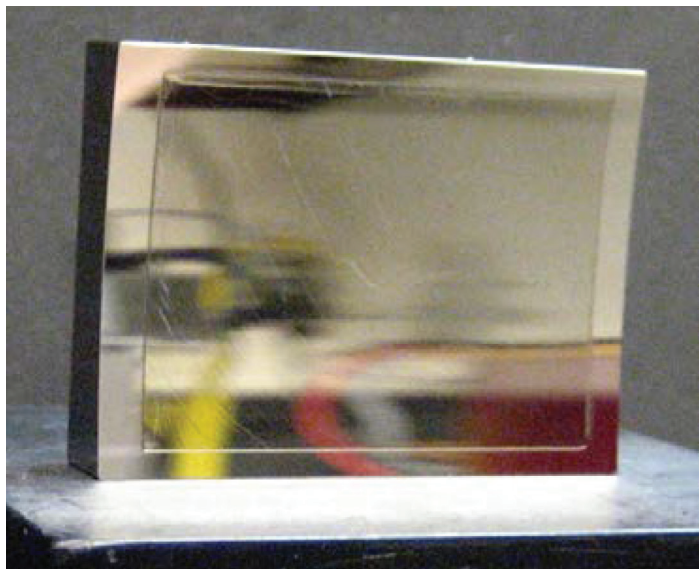
Although flat crystals can be used for some metrology applications, in many cases it is desirable to use a crystal which has been bent along one or two axes to facilitate focusing of the signal. Thick crystals can be bent by clamping and physically bending; however, the range of curvatures permitted is limited. More control and bending configurations are possible through the development of a two part assembly – a backing made from glass or metal with the desired curvature and a thin crystal which conforms to the backing.

SOFT X-RAY CRYSTAL PRODUCTION AT INRAD OPTICS

Inrad Optics has recently been awarded Phase I and II small business innovation research (SBIR) funding from the Department of Energy's Fusion Energy Sciences division. This support is being used to develop a US-based commercial source of bent soft x-ray crystals. Inrad Optics has leveraged its expertise and infrastructure to produce high-quality KAP and RbAP crystals and optimize processes for affixing crystals onto curved substrates. Crystal growth, substrate finishing, and assembly are conducted at our New Jersey facility. Inrad Optics offers KAP and RbAP as flat plates or mounted on cylindrical, spherical, toroidal, or ellipsoidal substrates. We specialize in fabricating bent crystal optics to customer specifications, and we welcome inquiries with custom geometries.



Example crystal boule of KAP grown at Inrad Optics.



Thin KAP crystal mounted to toroidally-bent substrate.

SOFT X-RAY CRYSTAL PARAMETERS¹

Crystal	2d spacing for (010) [Å]	Considerations
Potassium Hydrogen Phthalate KAP	26.6	Good general crystal for all low-Z elements down to O. Absorption edges: Potassium K-edge at 3.44 Å, Oxygen K-edge at 23.26 Å.
Rubidium Hydrogen Phthalate RbAP	26.1	Higher intensity than KAP for Na, Mg, Al K α and Cu L α (~3x), F K α (~4x), and O K α (~8x). Absorption edges: Oxygen K-edge at 23.26 Å, complicated Rubidium L-edge structure at 6.0, 6.65, and 6.87 Å.

References:

¹ X-ray Data Booklet, Lawrence Berkeley National Laboratory, Berkeley, CA 2009.