Effect of elastic anisotropy on crystal deformation*

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Abstract

Many crystals, such as silicon, germanium and diamond, are elastically anisotropic. Young’s modulus and Poisson’s ratio are direction dependent. Because anisotropic analysis is complicated, isotropic approximation is commonly assumed in optics design. This approach is valid for thermal-induced deformation. For mechanically deformed system, such as bendable optical substrate, anisotropy needs to be considered.

An optical substrate, in the form of plate, can be bent into a concave shape to focus an x-ray beam. The desired shape after bending could be cylindrical, elliptical, etc. Due to the Poisson’s effect, an anticlastic bending in the transverse direction occurs in the opposite direction (convex). As a result, the substrate is bent into a saddle shape. That is, when an incident x-ray beam is focused in one direction, it expands in the orthogonal direction. For an isotropic plate, the anticlastic bending radii depends on geometry and bending moment. However, for a crystal plate, the tangential and anticlastic bending radii depend on crystal plane and cut orientation, as well as the geometry aspect ratio (ratio of width to length). In general, elastic anisotropy of crystals may be exploited advantageously in optimal design of bendable substrates to minimize or maximum anticlastic bending. For examples, for tangential or sagittal focusing by a Bragg reflection, the anticlastic bending is undesirable and should be minimized; however, for sagittal focusing by a Laue crystal, the anticlastic bending can be used to provide better energy resolution.

In this presentation, single-crystal silicon anisotropy and its effects on substrate bending are discussed. Analytical, numerical, and experimental results are provided.

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