Development of a Two-dimensional Bender for Inelastic X-ray Scattering

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Introduction

With third-generation synchrotron radiation sources, spectroscopy with hard x-ray radiation with an energy resolution of a few meV became possible. The research areas for this kind of inelastic x-ray scattering cover a wide range, from phonon excitations in single crystals to dynamics in biological systems and electronic excitations. Recent reviews about the technique of inelastic x-ray scattering and research done with it are given in Refs. 1 and 2.

The goal of our effort is to develop a new method for producing analyzers and to push the energy resolution of these experiments to a lower limit of about 1 meV. At the same time, the analyzer's efficiency, which is primarily related to the quality of the focus, should be high.

Methods and Materials

The analyzer in a spectrometer of inelastic x-ray scattering has to fulfill two tasks: first, to filter the radiation coming from the sample with an energy resolution in the meV range, and second, to focus the x-rays into a detector. To provide the energy resolution in the meV range, an undistorted single crystal with a thickness of at least 1 mm is required. The approach here is to have individual pixels of silicon single crystals glued to a glass disk, which is bent to a spherical shape, so that all pixels focus to the same detector.

The analyzer was prepared as follows. First, a 4-in.-diameter and 4-mm-thick silicon disk was polished to a flatness of about 1 µm. One side was then cross-grooved about 2.5 mm deep with a high-speed diamond saw with a 300-µm-wide blade. The grooved side of the silicon was glued with epoxy to a 2-mm-thick, 5-in.-diameter glass plate with a flatness of a few µm. Finally, the silicon was cut through with a finer blade (50-µm wide), leaving pixels about 0.9 × 0.9-mm large and 4-mm tall on the substrate (Fig. 1). To remove the strain from the cutting, the substrate was etched in KOH.

Bending to a spherical shape with a radius of 6 m was done by putting the glass plate between two metal cylinders that had contact surfaces of different diameters (see Fig. 2). The bending radius can be changed by either mechanical screws or three step-motor-driven actuators. A detailed description of the setup is given in Ref. 3.

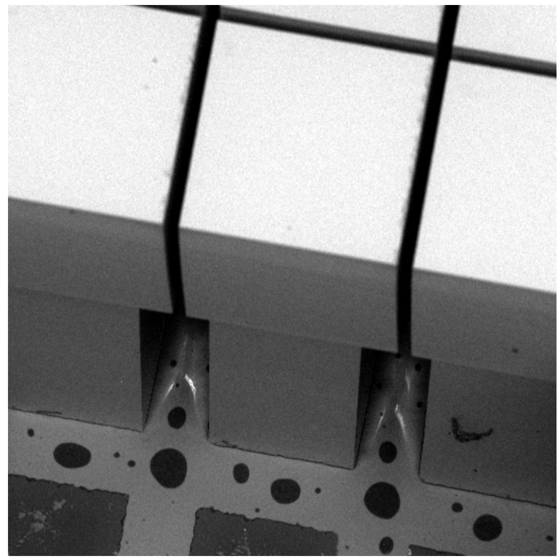

FIG. 1. Diced silicon pixels on flat glass substrate.

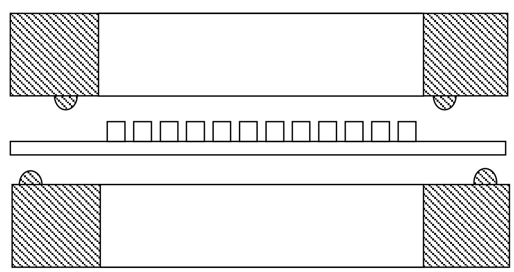

FIG. 2. Scheme of 2-D bender.

Results and Discussion

The bending performance was analyzed by optical interferometry. It showed that by adjusting the mechanical alignment screws, the deviation from a perfect sphere can be minimized to a peak-to-valley value of 5.6 µm with a mean square deviation of 0.8 µm. Over the largest part of the area, the deviation was less than 2 µm. The residual distortions observed are most likely due to initial figure errors of the glass plate.

A test of the analyzer was done at the 3-ID-C inelastic spectrometer [4]. The total energy resolution — 1.8 meV full-width, half-maximum (FWHM) at 21.657 keV of the spectrometer — was determined by using a piece of Plexiglas as a sample. When the resolution of the monochromator is taken into account, the resolution of the analyzer is about 1.3 meV, which agrees with the calculated value.

To obtain an even better energy resolution, the thickness of the silicon of the analyzer had to be increased to 8 mm. At 25.7 keV, a total energy resolution of 1.0 meV was obtained (Fig. 3), corresponding to 0.7 meV for just the analyzer.

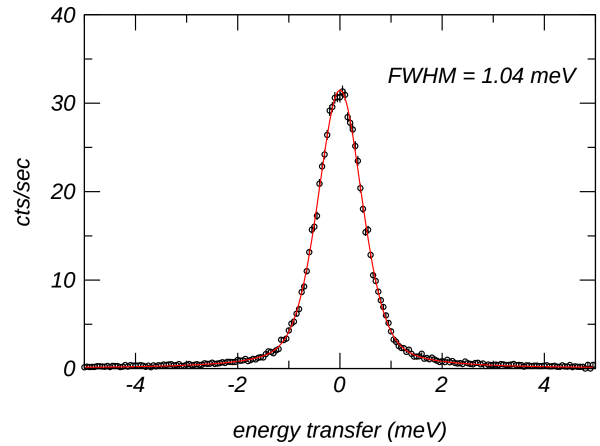

FIG. 3. Energy resolution measured with a piece of Plexiglas

Acknowledgments

Use of the APS was supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

References

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