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X-ray Polarimeter with Multi-layer coated CCD

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Introduction

We are developing an X-ray polarimeter using a transmission multi layer filter for the future astronomical usage. The transmission multi layer has the following advantages. (1) The imaging is easy by using the imaging detector. (2) If the band path for the polarization measurement is designed for soft X-rays, the filter is transparent for the hard X-rays. Thus by using the photon counting detector with moderate energy resolution, we can use this polarimeter as an imaging spectrometer for the hard X-rays.

The stand-alone filter of the multi layer has been known as a good polarimeter[1-2]. However the stand alone transmission multilayer filter is very difficult to handle and is not suitable for the future installation onto a satellite. A multi layer coated photo-diode has been reported but it can not image[3]. Therefore we are trying to deposit a multi layer directly onto the surface of a CCD, especially onto a back-side CCD. The multi-layer coated CCD can be an imaging polarimeter.

Multi Layers

Mo/Si multi layers have high reflectivity for 13.5nm X-rays. The reflectivity of 9 layer-pairs (3 nm Mo and 7 nm Si) for 45deg incident angle is calculated. The peak reflectivity is at 13.5 nm with more than 70% for S polarization, but ~1% for P polarization. This reflection property works as a polarization selected band pass filter. The transmission of the same multi layers on a substrate of 100 nm thick SiO_2 is also calculated. This SiO_2 thickness is a design value of the anti-reflection coating of our CCD, but is possible to make thinner. In the 13.5nm band, P polarization lights have ~20% transmission, but ~6% for S polarization. This filter is transparent for x-rays with short wave length less than 1nm. If we detect the transmitted x-rays with a position sensitive and energy resolved detector, such as a CCD, we can measure the image of a selected position angle for 13.5nm band and also can perform an ordinal spectroscopic-imaging observation for short wave length x-rays less than 1nm. The designed multi-layers (Mo/Si 9 layer pairs) are deposited onto the CCD at JAXA/ISAS, with a DC magnetron spattering method. The CCD is a back-side type, S7170-0909, made by HAMAMATSU Photonics. The pixel size is 24 μm square and the number of the pixels is 512×512.

Performance Evaluation

The multi-layer-coated CCD was exposed to the polarized X-ray beam at the BL-12A in Photon Factory. The BL-12A is designed for soft X-ray experiments from 30 eV to 1000 eV. A grating spectrometer is installed and the energy resolution is less than 0.1 nm. We used the beam from 70 eV to 120 eV. In order to block the 2nd order light, a Be filter was used for the experiment from 70 eV to 95 eV and a B filter was used from 94 eV to 120 eV. The CCD was installed on a rotational rod, which can be manually rotated from the outside of the vacuum chamber. The beam is aligned to coincide to the rotational rod. We measured the detected intensity as a function of the photon energy and of the rotation angle. Figure 1 shows the ratio of the detected intensity to that of the S polarized beam as a function of the rotational angle for several energies.

We confirmed the multi-layer coated CCD works as an imaging-polarimeter[3]. However, more precise experiment is needed for quantitative evaluation. Especially the estimation of the amount of the higher order light and the reduction of it are required.

References

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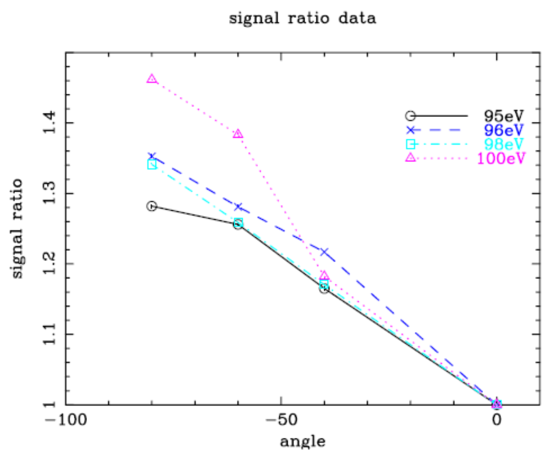

Figure 4. The CCD before the depositing the multi-layer. In order to restrict the depositing area, a cover is installed.

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