EUV transmission of Optical Blocking Filter and Optical Blocking Layer for Soft X-ray Imager (SXI) onboard Astro-H

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Abstract

We have developed the X-ray CCD camera system for the Soft X-ray Imager (SXI) which will be launched as focal plane detectors of X-ray telescope onboard the Japanese 6th X-ray astronomical satellite, Astro-H. The X-ray CCD is back-illuminated (BI) CCD which has an Optical Blocking Layer (OBL) directly coating its X-ray illumination surface with Aluminum-Polyimide-Aluminum instead of Optical Blocking Filter (OBF). The X-ray CCD is affected by large doses of extreme ultraviolet (EUV) radiation from Earth sun-lit atmosphere (airglow) in orbit. To evaluate the performance of polyimide that cut off EUV, we measured the EUV transmission of both OBL and OBF at various energy range between 15–72 eV by utilizing beam line located at the Photon Factory in High Energy Accelerator Research Organization (KEK-PF) in this March and June, and obtained the EUV transmission to be 3% at 41 eV which is as same as expected transmission from the designed thickness of polyimide layer.

Key words: instrumentation: detectors — X-ray CCDs; Optical Blocking Filter; Optical Blocking Layer

1. Introduction

He ions are the second major component around the Earth and resonantly scatter the solar He II EUV emission (304Å= 41 eV). This HeII emission is so strong (8×10^6 photons $\mathrm{cm^{-2}s^{-1}sr^{-1}}$) that we have to block the He II emission line for the X-ray CCD onboard X-ray satellite on-orbit.

Since a X-ray CCD, especially Back-illuminated CCD (BI-CCD), has high detection efficiency for Optical and EUV as well as soft X-ray, we have used an OBF in front of a CCD chip. XIS-CCD onboard Suzaku satellite has equipped with the OBF, which is composed of a thin polyimide ($C_{22}H_{10}O_4N_2$) layer sandwiched by two Al layers (Kitamoto et al. 2003, Koyama et al. 2007). The thickness of polyimide layer and the Al layers are ~1400Å and ~800+400Å, respectively. Polyimide and Al has a capability to cut EUV and optical light, respectively, which causes in increase in dark current. But the thickness of OBF is so thin that OBF is always in danger of tearing by the acousmato or vibration during the launch, and it is difficult to handle on the ground.

In stead of OBF, We have developed OBL with Hamamatsu Photonics, K.K, which is composed same design of OBF, polyimide layer sandwiched by Al, and directly coated BI-CCD. We are going to employ OBL for SXI (Tsunemi et al. 2008). Thanks to OBL, we can make the thickness of polyimide thinner and ,as a result, the quantum efficiency of SXI camera in the soft X-ray range can be higher. Out primary goal of EUV transmission of OBL is ~1% at 41 eV to block EUV from sun-lit atmosphere.

In this paper, we report the EUV transmission of both

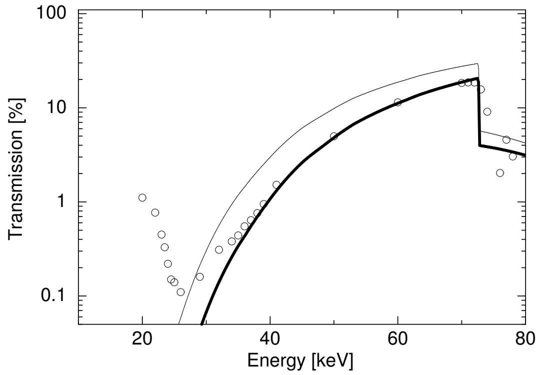

Fig. 1. EUV transmission of the OBF as a function of EUV energy. The Al-L edge absorption structure above ~70 eV is clearly seen.

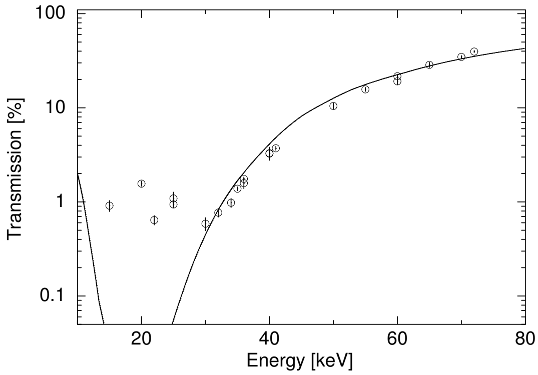

Fig. 2. EUV transmission of the polyimide of OBL as a function of EUV energy. The model line is assumed the thickness of polyimide is 1100Å.

OBL and OBF.

2. Measurement of EUV transmission of OBL and OBF

We measured EUV transmission of both OBL and OBF at Beam line 20A in KEK-PF, which can provide EUV from 10–80 eV using the 3-m normal incidence monochromator. The EUV beam was restricted by a slit, resulting in a beam size of ~2 mm× ~2 mm. We set the thin Al filter (~1000Å) in the gate valve to eliminate the higher-order light. We also set the OBF in another gate valve, and the OBF could be put in and out of the EUV beam. The OBF was made by Luxel Co. LTD and the thickness of Al and polyimide of OBF measured by Luxel Co. LTD was 1030±50Å and 1129±100Å, respectively.

In the vacuum chamber, we set both window-less photodiode and BI-CCD. The BI-CCD chip has two Al layers coating of 400Å and 800Å on its full surface area, and has a polyimide layer (1100Å) on its half surface area. Hereafter we named the both polyimide and Al coating area on the CCD chip 'polyimide area' , and named the only Al coating area 'non-polyimide area'.

The EUV transmission of an OBF was calculated as a ratio of currents measured with photodiode with the OBF and one without it. BI-CCD was mounted on the X-stage in the Vacuum Chamber and we could irradiate alternately the polyimde area and non-polyimide area with the beam. The EUV transmission of a polyimide layer of OBL was calculated as a ratio of the CCD signal measured with polyimide area to that with non-polyimide area.

We measured the EUV transmission of OBF and OBL in the energy range from 15 eV to 72 eV. Derived EUV transmission of OBF and OBL are shown in Fig. 1 and Fig. 2, respectively.

3. Result and Discussion

The thin line is calculated transmission from the design value reported from Luxel Co LTD (Fig.1). This calculated transmission clearly exceed our measurement results at all energy range. The heavy line is our modeled transmission curve assuming the thickness of Al and polyimide is 950Å and 1220Å, respectively, and we also apply an extra Al_2O_3 layer (110Å) in our model. In previous works (Kitamoto et al. 2003), the oxidation of Al has been pointed out and their results support this model. The measured EUV transmission of OBF is seemed to be well explained by our model, and thickness of both polyimide layer and Al layer is consistent with the design value within the error, even if we add the thickness of Al_2O_3 layer as the Al layer.

The EUV transmission of polyimide of OBL is ~3% at ~41 eV (Fig. 2). The solid line is calculated transmission from the design value reported from Hamamatsu Photonics, K.K. Our measurement result is seemed to be well explained by this calculation.

More quantitative discussion about the thickness of polyimide layer, Al layer, and Al_2O_3 layer is beyond the aim of this paper. We will measure the X-ray transmission of OBL and OBL to evaluate the thickness of these three layers.

From these results, we confirmed the polyimide layer of OBL directly coating the BI-CCD chip can block EUV well, and we found the OBL with 1100Å polyimide layer and 1200Å Al layers has a capability to satisfy nearly our requirement to block EUV from sun-lit atmosphere. The hump structure below 30 eV is seen in both Fig. 1 and Fig. 2 and this structure might be caused by higher order EUV below Al-K edge (~70 eV). The origin of this structure is under investigation.

References

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