7732-119

Measuring the EUV and optical transmission of the optical blocking layer for x-ray CCD camera

T.Kohmura, T. Watanabe, K.Kawai , T.Ogawa, S.Ikeda, K.Ushiyama, K. Kaneko, M.Kawashima (Kogakuin Univ), S. Kitamoto, H. Murakami, E. Takenaka, K. Nagasaki, K. Higashi, M. Yoshida (Rikkyo Univ), H. Tsunemi, K. Hayashida, N. Anabuki, H. Nakajima, M.Uchida, S.Ueda (Osaka Univ), T.G. Tsuru (Kyoto Univ), T. Dotani, M. Ozaki, A. Bamba, K. Matsuta, T. Fujinaga (ISAS/JAXA), J. Hiraga (Univ of Tokyo), K. Mori (Univ of Miyazaki), and ASTRO-H SXI team

Abstract

We have newly developed the 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). OBL is composed of a thin polyimide layer sandwiched by two Al layers. Al and Polyimide has a capability to cut visible light and EUV, respectively. To evaluate the performance of polyimide of OBL 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). We obtained the EUV transmission to be ~3% at 41eV which is as same as expected transmission from the designed thickness of polyimide layer. We also found no significant change of the EUV transmission of polyimide found during 9month. We also measured the Optical transmission of OBL between 500-900 nm to evaluate the performance of Al that cut off optical light, and obtained the optical transmission to be less than 4×10^{-5}.

1. EUV and Optical measures for X-ray CCD

He ions are the second major component around the Earth and resonantly scatter the solar He II EUV emission (304Å=~41eV) (See Fig.1). This HeII emission is so strong (8×10^{6} photons $cm^{-2}s^{-1}sr^{-1}$) that we have to block this He II emission line for the X-ray CCD onboard X-ray satellite on-orbit because the X-ray CCD, especially the BI-CCD, has a high sensitivity not only to X-ray but also to visible light and EUV, it is necessary to cover entering the visible and EUV light entering into the BI-CCD.

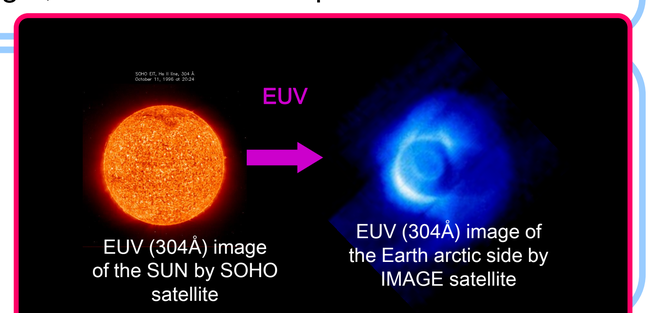

Fig1.EUV image of the Sun (Left) and the Earth (Right).

2. What is OBL?

Since a X-ray CCD, especially BI-CCD, has high detection efficiency for Optical and ultra-violet light as well as soft X-ray, we have used an OBF in front of a CCD chip. XIS-CCD onboard Suzaku has equipped with the OBF, which is composed of a thin polyimide ($C_{22}H_{10}O_4N_2$) film sandwiched by Al. Polyimide and Al has a capability to cut ultra-violet and optical light respectively, which causes in increase in dark current. But the thickness of OBF is so thin that it was difficult to handle on the ground.

In stead of OBF, we have developed OBL, which is made by Hamamatsu Photonics K.K. OBL is composed same Design of OBF, Polyimide film sandwiched by Al, and is directly coated Back-illuminated CCD (BI-CCD). 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 less than 1% to block EUV light from sun-lit atmosphere .

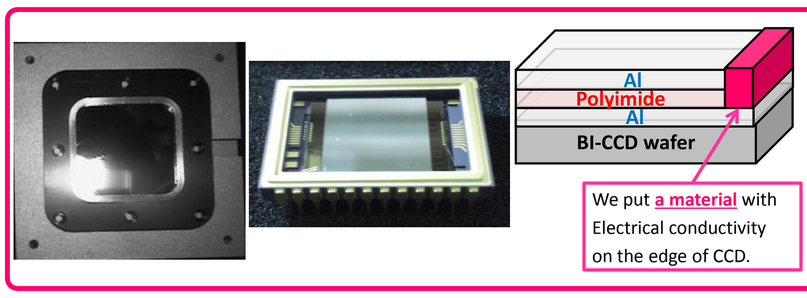

Fig 2. (Left) : Picture of Suzake OBF The size of this OBF is ~3cmX~3cm. The silver area is the OBF inside the black frame.
(Middle) : BI-CCD directly coated with OBL. The pixels size is 24μmX24μm. Total pixels is 512X512pixels. All surface area of this CCD chip is covered with Al, only half area is covered with Polyimide (Left area).
(Right) : Schematic view of OBL on the CCD wafer.

Table 1 : OBF vs OBL

OBF VS OBL	thickness[Å] Al/Polyimide	Tolerance vibration	Handling	past achievements	Manu-facturer
OBF (**O**ptical **B**locking **F**ilter)	1200 /1350	×	×	Suzaku, Chandra, etc	Luxel
OBL (**O**ptical **B**locking **L**ayer)	1400 / 1200	○	○	MAXI ※single layer of Al	HPK

3. EUV transmission of OBL

We measured EUV transmission of the OBL at Beam line 20A in KEK-PF twice in June 2009 and March 2010. Three OBL CCDs were measured (see Table2). This beam line can provide EUV from 10-80eV using the 3-m normal incidence monochrometor. The EUV beam was restricted by a slit, resulting in a beam size of ~2 mm×~2 mm. EUV images obtained with the BI-CCD and our experimental system are shown in Fig. 3 and Fig4, respectively. We set the thin Al filter (~1000Å) in the gate valve to eliminate the higher-order light. BI-CCD was installed in the Vacuum Chamber.

Table2 : Thickness of the Materials of Three OBL CCDs

CCD-ID	Al	Polyimide	Al
Pch18 03-07	400±100	1100±100	1000±100
Pch18 05-21	400±100	2350±100	1000±100
Pch18 13-13	400±100	2950±100	1000±100

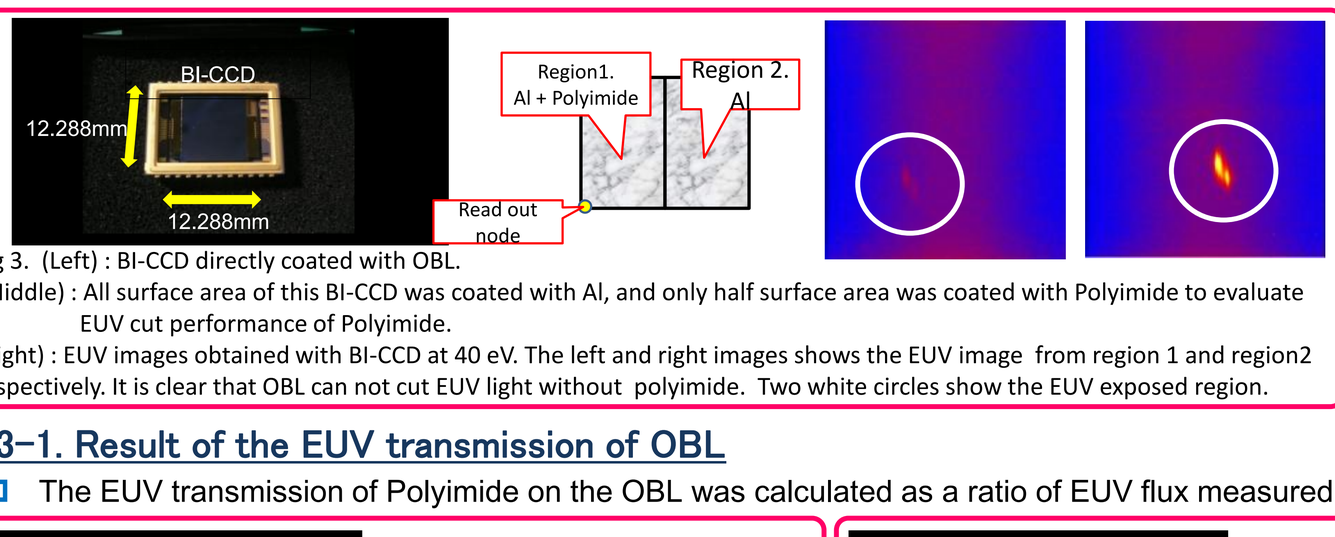

Fig 3. (Left) : BI-CCD directly coated with OBL.
(Middle) : All surface area of this BI-CCD was coated with Al, and only half surface area was coated with Polyimide to evaluate EUV cut performance of Polyimide.
(Right) : EUV images obtained with BI-CCD at 40 eV. The left and right images shows the EUV image from region 1 and region2 respectively. It is clear that OBL can not cut EUV light without polyimide. Two white circles show the EUV exposed region.

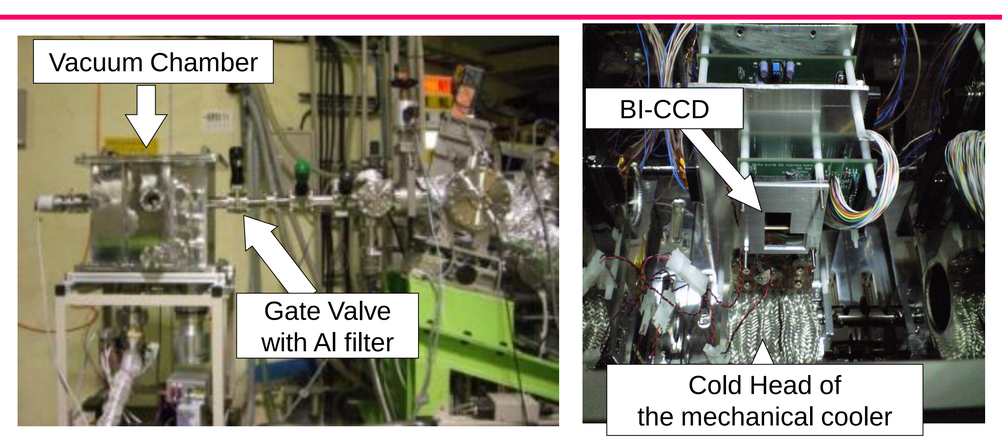

Fig 4. (Left) : Set up at BL-20A in KEK-PF . EUV light is radiating from the right hand side in this picture. (Right) : CCD in the vacuum chamber. The vacuum level and CCD temperature was 10^{-7}mbar and -55 deg, respectively.

3-1. Result of the EUV transmission of OBL

The EUV transmission of Polyimide on the OBL was calculated as a ratio of EUV flux measured with BI-CCD with Polyimide and one without it.

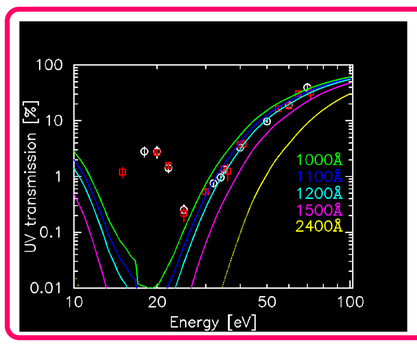

Fig5. EUV transmission of the polyimide of OBL. Five lines show the calculated transmission.
For example, we assumed the thickness of polyimide is 1100 Å which is derived from the design value. There is the residual below 23eV, where the data are affected by the contamination of the higher order light at the beam line.

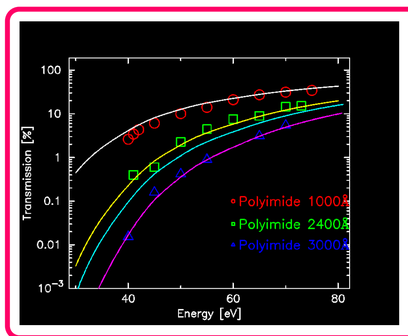

Fig6. The red circle and green square shows the EUV transmission of Polyimide, with 2400Å and 3000Å thickness, respectively.

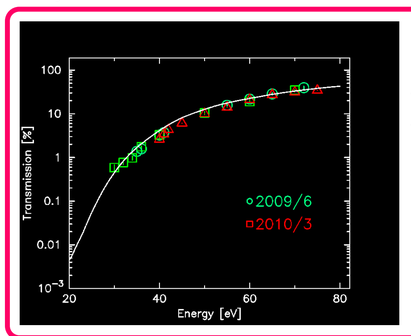

Fig7. The white line is the modeled transmission curve assumed the thickness of polyimide to be ~1100A (design value). We found there was not difference of the EUV transmission during 9 month comparing the first and second experiment at KEK-PF(red circle and green square).

4. Optical transmission of OBL

We measured the Optical transmission of the OBL at our Lab. Using optical light from a halogen lamp is introduced to a grating monochrometer, we can radiate the monochrome visible light to BI-CCD which is installed in the vacuum chamber. The measured wave length range is from 400nm to 900nm. Two kinds of filters were used to eliminate the higher order light, changing according to the measurement wave length.

Two type of BI-CCDs were used in this experiment. One is BI-CCD with OBL, the other is without OBL. We installed these BI-CCDs alternately in the vacuum chamber, and radiate the visible light respectively. Then the EUV transmission of the OBL was calculated as a ratio of Optical flux measured with BI-CCD with OBL and one without it. The resultant transmissions of the OBL is shown in Figure8.

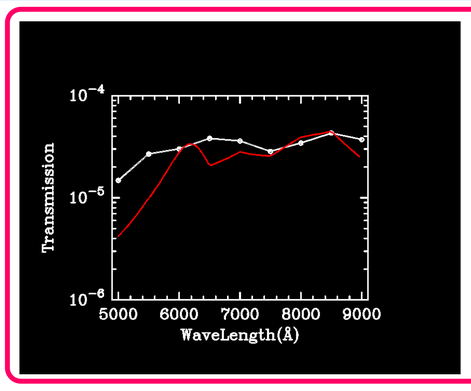

Fig8. Optical transmission of OBL. The white circles is result of our experiment, and the red line is assumed the thickness of Al is ~50 Å and 800 Å which is thinner value than the design value (see table2). The expected optical transmission was less than 10-5 in the visible range. This discrepancy might be caused by the oxidation of Al which was reported by the previous work[1,2].

5. Summary

We found the EUV transmission of all polyimide of OBL was consistent with the expected value from the design thickness of polyimide. We also found no significant change of the EUV transmission of polyimide found during 9month. The optical transmission of OBL was higher value than the expected value from the design thickness of OBL. This discrepancy might be caused by the oxidation of Al. To confirm this result, we will measure the X-ray transmission of OBL. We plan to install the X-ray CCD camera with OBL (SXI, Soft X-ray Imager) onboard the ASTRO-H[3,4].

Reference

[1]Kohmura,T., et al., 2000, Adv. Space Res. 25, 877
[2]Kitamoto, S., et al., 2003, NIM A, 505,(683-687)
[3] Takahashi, T., et al., "The ASTRO-H Mission ", in this conference., *Proceedings of SPIE,* ***7732-34, this issue,*** (2010)
[4] Tsunemi, H., et al., "Soft X-ray Imager (SXI) Onboard ASTRO-H", in this conference., *Proceedings of SPIE,* ***7732-35, this issue,*** (2010)