THE DEVELOPMENT OF A BACK-ILLUMINATED SUPPORTLESS CCD FOR SXI ONBOARD NEXT

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ABSTRACT

We give overview and the current status of the development of the Soft X-ray Imager (SXI) onboard the NeXT satellite. SXI is a back-illuminated supportless CCD (a combination of “back-illuminated CCD” and “supportless CCD”) whose imaging area and the supportless region are $42\times42\mathrm{mm}^2$ and $30\mathrm{mm}\phi$, respectively. The goal of the thickness of the depletion layer is $300\mu\mathrm{m}$, which enables us to cover the energy range of $0.3-25$ keV. The evaluation model 'CCD-NeXT1' with the size of $24\times48\mathrm{mm}^2$ shows no performance change due to the thinning process. The test model of P-channel CCD was confirmed to have high quantum efficiency above 10 keV with an equivalent depletion layer of $300\mathrm{m}$.

Key words: LaTeX; the NeXT satellite; X-ray CCD.

1. SXI ONBOARD THE NEXT SATELLITE

The 5th Japanese X-ray astronomical satellite, NeXT (New X-ray Telescope), is proposed to be launched around 2012 in order to investigate the non-thermal universe, such as hard X-ray components in galaxy clusters and SNRs, hidden AGNs and their contribution to the cosmic X-ray background (1). The NeXT satellite will be equipped with three sets of hard X-ray telescopes with multilayer supermirrors (Hard X-ray Telescope: HXT) focusing hard X-rays up to $60\sim80$ keV (2), and a wide-band camera (Wideband X-ray Imager: WXI) as the focal plane detector of HXT.

An X-ray CCD is one of the most popular focal plane detectors for the modern X-ray satellites like Chandra, XMM-newton and Suzaku, because of its well balanced good performances on the spectroscopy, imaging and time resolution (3; 4; 5). However, achieving a quantum efficiency of 10% for X-ray with an energy of 40 keV requires a depletion layer of $\sim1000\mu\mathrm{m}$, which is almost impossible. High Z material is essential to detect such hard X-rays. On the other hand, the performances below 10 keV of the high Z solid detectors such as CdTe are poorer than those of X-ray CCD. Thus, no single detector can cover the entire 0.3-80 keV band with the best performances. Thus, we have been developing a hybrid camera WXI, by combining the X-ray CCD and a CdTe pixel detector (6; 7; 8; 9). As shown in Figure 1, WXI consists of two sub-instruments; the soft X-ray imager (SXI) and the hard X-ray imager (HXI). SXI is a CCD camera with a thick depletion layer for the lower energy band below 10-20 keV. HXI is based on CdTe pixel detector covering the hard X-rays above 10-20 keV (10).

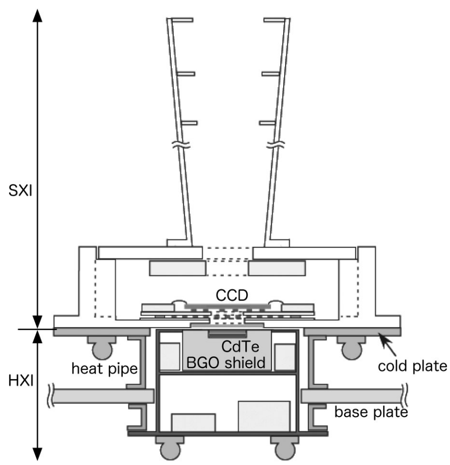

Figure 1. The schematic view of the WXI.

SXI is required to detect soft X-rays efficiently and pass hard X-rays through the CCD toward the CdTe pixel detector of HXI without excessive loss of photons. Since energy and position resolution of the CCD is superior

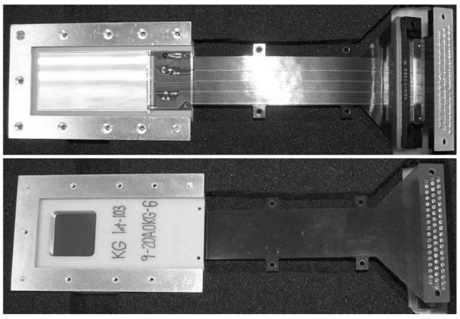

Figure 2. The upper and lower pictures show the CCD side and the back side of CCD-NeXT1, respectively.

to those of CdTe, it is desirable for the CCD to have as high a quantum efficiency for hard X-rays as possible. From the discussion stated above, the supporting package below the imaging area of the CCD in SXI is removed in order to pass the hard X-rays toward HXI without loss (a supportless CCD). Additionally, we adopt a back-illuminated CCD by removing the field free region in order to improve the quantum efficiency at the lower X-ray energy (a back-illuminated CCD). The removal of the field free region from the CCD also improves the quantum efficiency around the X-ray energy of 10 keV. Thus, in SXI, we develop a new type of CCD, 'a back-illuminated supportless CCD', in which the both of the back supporting package and the field free region are removed.

2. CURRENT STATUS OF THE DEVELOPMENT

N-channel CCD and CCD-NeXT1 In order to confirm the principle of the supportless CCD, we processed and evaluated a small test model with the size of $12 \times 12 \mathrm{mm}^2$, a depletion layer of $\sim 70\mu\mathrm{m}$ and the total thickness of $\sim 150\mu\mathrm{m}$. We found no performance degradation due to the thinning process (11). Next, we have constructed an evaluation model 'CCD-NeXT1', whose pixel size and format are $12 \times 12\mu\mathrm{m}$ and 2000×4000, respectively (Figure2). CCD-NeXT1 is confirmed to have the depletion layer of $77\mu\mathrm{m}$, the read out noise of $5\mathrm{e}$ (RMS) and the energy resolution of $140\mathrm{eV}$ for 6 keV X-rays. After the successful development of the small test model, We have been examining "CCD-NeXT2" with the imaging area of $49 \times 49\mathrm{mm}^2$, which matches the required size for SXI.

P-channel CCD In order to achieve high quantum efficiency for hard X-rays, we have been developing P-channel CCD, which is a new type of CCD collecting holes instead of electrons, from early 2002 together with National Astronomical Observatory of Japan (12). As given in Figure 3, high quantum efficiency equivalent with the depletion layer of $\sim 300\mu\mathrm{m}$ has been already achieved (11). We also have processed the fully depleted back illuminated type of the CCD with the thickness of $200\mu\mathrm{m}$, successfully. We have started processing an evaluation model "CCD-NeXT3" whose pixel size and format are $15 \times 15\mu\mathrm{m}^2$ and 2000×4000, respectively.

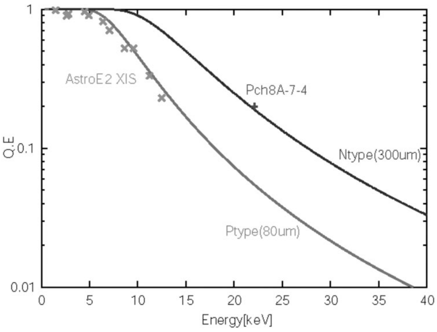

Figure 3. The quantum efficiency of P-channel CCD Pch8A-7-4 compared with the one of XIS (FI-CCD) onboard Suzaku

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