Screening and Optimization of Flight Model CCDs for Soft X-ray Imager (SXI) onboard ASTRO-H

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Abstract

Soft X-ray Imager (SXI) is the primary imaging instrument onboard the X-ray astronomical satellite ASTRO-H. Given the focal length of 5.6 m, four large-area P-channel CCDs cover a region of 38°×38° on the sky combined with the Soft X-ray Telescope. The criteria for the screening are derived as follows in the imaging and spectroscopic point of view: Defects such as hot column (<10) and hot pixels (<50), the detection of the Oxygen K-shell line (0.52 keV), the energy resolution at 6keV (<200 eV (FWHM)), the charge transfer inefficiency per transfer (<2×10^{-5}), and the dark current (<1 e-/pix/sec). Utilizing a test bench in the clean room at Osaka University, we have given the priority among the flight candidate devices after eliminating the chips that did not clear the imaging criteria. The flight model and back-up devices have been selected. All of them satisfied the above criteria and delivered for the calibration. We have also finalized the time profile of the clocking (micro-code) and operating voltages.

Key words: Instrumentation: detectors, Techniques: imaging spectroscopy

1. SXI-S-CCD

Here are the SXI-S-CCD and its various factors or elements.

- Back-side illuminated P-ch CCD (measure num. of holes)
- Wafer thickness: 200 µm (fully depleted)
- Pixel size: 24 µm×24 µm
- On-chip binning: 2×2
- Wafer size: 30 mm×60 mm
- Working temperature: -120 °C
- Manufactured by Hamamatsu

Since the optical axis of the telescope resides in CCD2, it should have the best performance. Considering the case that the observation target is bright in visible light, the evaluation items must include the uniformity of the thickness of the optical blocking layer (OBL) as well as the X-ray imaging spectroscopic performances. Given the results of the screening, the best four chips become flight model (FM), while the second-best four chips are the backups.

2. Screening System

We measured the amount of contaminant on the cold plate using TQCM (Thermoelectric Quartz Crystal Microbalance) sensor prior to the screening. The accumu-
lating rate in our chamber is was $8.5 \times 10^{-9}$ g/min, which is factor of three better than that of the calibration chamber used for CCDs onboard Suzaku. Hence we conclude that our chamber for ASTRO-H CCDs are satisfactorily clean. We will also measure the amount of the left contaminant after the screening with the witness plate.

We irradiate the devices with $^{55}$Fe (5.9 keV), Si (1.7 keV), O (0.52 keV) and LED light (570 nm). Evaluating items are follows:

- Energy resolution for $^{55}$Fe and O
- Vertical CTI (Charge transfer inefficiency)
- Horizontal CTI
- Flux ratio between Si and O
- X-ray response in the low energy band
- Dark current
- Uniformity of the thickness of OBL

3. Result
3.1. Screening
Half of the 24 devices satisfied the imaging criteria. We have kept scores against the devices and then determined the position in the focal plane assembly as shown in Fig. 5.

3.2. Optimization of the operating voltage and micro-code
We search the optimum operating voltage of the P-ch NeXT4. All of the gates and drains other than the one under evaluation are fixed to the nominal voltages. Performance evaluation items are as follows:

- Gain(Gauss center of O, Si and $^{55}$Fe)
- Energy resolution(FWHM of O, Si and $^{55}$Fe)
- Spectroscopic performance (Gauss center over FWHM of O, Si and $^{55}$Fe)
- Readout noise

Black colored values in Fig. 6 are voltages that shows best performances. Green ones are slightly worth than best values in performance but we can use them. Red colored are too bad to use in space. We also optimized the micro-codes. Micro-codes describe the time profile of all the clocking gain and drains. We optimized duration and timing of the following items:

- Reset Gate: Clear the floating diffusion amplifier at the edge of the readout node.
- Charge Injection : White lines in Fig. 5.

Fig. 3. Inside view of the chamber. The signals from CCDs are processed by the Video ASIC onboard the video board that locates outside the chamber.

Fig. 4. Example spectra obtained with FM candidate devices (ID : FM01-22). Only single pixel events are extracted. Even $\overline{0}$ and odd $\overline{1}$ represent analog-to-digital converter in the ASIC.

Fig. 5. Frame images of the four FM candidate devices that are configured so that they form look-up view as Fig. 2. White lines are the artificially injected charges to mitigate radiation damage in orbit, although the position of the charges are not yet optimized.

Fig. 6. List of the optimum operating voltages of P-ch NeXT4.

References