

Performance verification of detecting soft X-rays with a next generation Si CMOS detector for space applications

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An all-sky survey of X-ray transient objects in the soft X-ray band is essential to discover mysterious electromagnetic counterparts of gravitational-wave sources, and observe high-redshift objects to probe unexplored physical conditions in the early universe. HiZ-GUNDAM is a future satellite mission to realize this in the soft X-ray band (0.4–4 keV). The X-ray detector of HiZ-GUNDAM has Si pixel sensors that require a fine positioning accuracy (e.g. tens of micrometer), a high-detection efficiency, large detection area (tens of cm²) and, relatively high frame rate of ~ 10 frames s⁻¹. A back-illuminated Si CMOS image sensor can satisfy these requirements. For basic development, GSENSE400BSI-TVISB, fabricated by Gpixel Inc., with 2048 × 2048 pixels of size 11 μm, was selected. We conducted a detailed study on the spectroscopic performance of CMOS in the soft X-ray band and its radiation tolerance for space applications. When the CMOS was irradiated with low-energy X-rays in a vacuum environment fluorescent Al Kα X-ray at 1.49 keV and other similar low-energy lines were clearly detected. Furthermore, detection efficiency >50% was achieved in the soft X-ray band, corresponding to ~ 10 μm thickness of the depletion layer. We also evaluated radiation tolerance against high-energy gamma-rays (⁶⁰Co for 30 krad) and 100-MeV protons (4.8×10^{10} proton cm⁻²). The results showed that an increase in dark current was suppressed by cooling to less than -20 °C with an exposure time of ~ 0.1 s, and X-rays above 0.4 keV could be detected even after irradiation. In addition, we investigated radiation tolerance of low energy charged particles using alpha particles from ²⁴¹Am. Considering the physical structure of CMOS, we selectively irradiated the CMOS depletion and circuit layer with alpha rays by adjusting the Bragg peak positions. We found that even for high doses, a low detectable energy of 0.4 keV was achieved.

Submission declaration

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