CCD Imagers for Soft X-ray Astronomy*

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We describe the development at Lincoln Laboratory of large-area CCD arrays for soft x-ray spectroscopic imaging. One such array consists of four, closely abutted, 420×420-pixel CCDs for the Astro-D satellite to be launched in February 1993. This imager has a frame-transfer format with 27×27-μm pixels. Future missions include the Advanced X-ray Astrophysics Facility (AXAF) to be launched later in this decade which will use a larger format chip (approximately 1000×1000 pixels).

Among the technical challenges of these programs is the use of high-resistivity wafers in order to achieve deep depletion depths. Deep depletion is necessary for good quantum efficiency at energies greater than 4 keV. Careful gettering and clean processing are necessary to maintain high resistivity and minority-carrier lifetime through the device fabrication process. For the Astro-D devices we maintained the starting resistivity of 6500 ohm-cm (p-type) and the minority-carrier lifetime greater than 1 ms through the process. MOSFETs made on such lightly doped material are often subject to severe short-channel effects, but we found that the charge-sensing buried-channel FET on the Astro-D chips performed satisfactorily in spite of its short channel length (2 μm). Noise levels of 3 to 4 e- rms were routinely achieved at serial data rates of 50 kHz.

Space-radiation effects are also a major concern for these devices. To minimize the effects of displacement damage arising from energetic particles (primarily protons) we have added a narrow potential trough along the center of both the parallel and serial registers. This trough confines the small x-ray-generated charge packets to a reduced volume in order to minimize trapping effects from this damage. A trough width of 2 μm in the imaging array has been found to reduce CTI by almost ten-fold compared to a non-trough device. A second radiation problem are the ionization events arising from non-x-ray background radiation. These events add significant signals that must be distinguished from the x-ray events. Imagers made on high-resistivity bulk wafers with long carrier lifetimes are particularly vulnerable to this problem. Although the problem can be minimized by thinning the wafer, we have devised a novel solution which avoids the hazards of processing and handling thin wafers. Our method uses a reverse-biased pn

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junction on the back of the wafer to deplete most of the otherwise neutral bulk region. Unwanted ionization events that occur in the depletion region of this junction are collected before they can drift to the CCD depletion region at the front of the device.

Device screening and packaging for the Astro-D focal planes will be described. In addition, we will discuss some of the device and packaging issues concerning the AXAF mission.

$N = \frac{E}{3.65\ \text{eV/EHP}}$

Fano noise

read noise $< (F N_e)^{1/2}$, $F = 0.1$

for $E = 100$ eV, Fano $= 1.7e^-$

Poly gate 180nm thick

6500 Ω·cm material. $N_A = 2.17 \times 10^{12}/\text{cm}^3$ (p-type)

Use trough (notch)

CTI $< 10^{-5}$