



Design and Development of an Event-driven SOI Pixel Detector for X-ray Astronomy and Light Dark Matter Search

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Outline

- Introduction for X-ray Astronomy
- XRPIX Design Description
 - -> XRPIX5: Our first prototype for a large-area device
- First Results of XRPIX5
- Plan for Light Dark Matter Search
- Summary

Standard imaging spectrometer of modern X-ray astronomical satellites ...

-> X-ray CCD : Wide and fine imaging with the sensor size of ~20 – 30 mm, pixel size of ~30 µm sq. Fano limited spectroscopy with the readout noise ~3 e⁻ (rms).

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XRPIX for Future X-ray Astronomy



SOI Pixel Detector

- A monolithic pixel detector with silicon-on-insulator (SOI) CMOS Technology -> $0.2 \ \mu m$ fully-depleted (FD) - SOI pixel process
- SOI Pixel Detector (SOIPIX) : Processed by LAPIS Semi. Co., Ltd.

SOIPIX Advantages

- No mechanical bump bonding -> High Density, Low Parasitic Capacitance, High Sensitivity
- Standard CMOS circuit can be built
- Based on industrial standard technology

SOI Pixel Process

New Process to make pixel detector with SOI technology joint development with LAPIS Semi. Co., Ltd.

Our group presentations:

Ms. Y. Yoshihara (poster, 8th Sep. 11:00 -, 16:55 -) Dr. R. Hashimoto (next talk, 8th Sep. 12:05 -) Ms. S.Bugiel (8th Sep. 17:40 -)

Basic Components

Circuit Layer : ~40 nm Buried Oxide (BOX) : 200 nm Sensor Layer : 100 - 725 μ m



History of XRPIX Series



History of XRPIX Series



Design Specification of XRPIX5



Our first prototype for a large-area device

Components

- Chip size : 24.6 mm x 15.3 mm

(Effective area : 21.9 mm x 13.8 mm)

- Pixel size : 36 µm sq.
- # of pixel : 608 x 384 (= ~233k)
- Thickness of sensor layer : 310 μm (CZ wafer) 500 μm (FZ wafer)

<u>Other</u>

Programmable Gain Amplifier (PGA) circuit for column line.

Differential output of signal and pedestal level.

We considered more suitable architect constitution for event-driven readout.

-> 8 x 8 pixel readout per unit.

Pixel and Analog Signal Readout Circuit



Event-driven Readout

XRPIX



DAQ Setup for XRPIX5

Soi EvAluation Board with Sitcp (SEABAS) : General data readout board for SOIPIX.



Spectroscopic Performance







Plan for Light Dark Matter Search

N.Oka et al., arXiv:1507.06987 Advantage of XRPIX

We are planning a light dark matter search using XRPIX.

- Low energy threshold
- BG rejection by anti-coincidence (CCD can not) -> External and internal BG can be reduced.
- X-ray will be the ultimate BG.



Summary

- We have been developing an event-driven SOIPIX sensor, "XRPIX", for future X-ray astronomical satellite mission.
- We realize the event-driven readout mode and very low non-X-ray background by the function of the trigger signal output.
- We designed the first prototype, "XRPIX5" to achieve a large-area device for satellite loading.
 - -> chip size: 24.6 mm x 15.3 mm, pixel size: 36 µm sq., number of pixel: 608 x 384 (= ~233k)
 - -> readout noise: 48 e⁻ (rms), 580eV (4.1%) @ 13.95 keV (FWHM)
- We will optimize operation and evaluate characteristics uniformity of XRPIX5.
- We are planning a light dark matter search using XRPIX.

Backup



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Smart CutTM



LAPIS 0.2 µm FD-SOI Pixel Process

Process	0.2µm Low-Leakage Fully-Depleted SOI CMOS (LAPIS)
	1 Poly, 5 Metal layers, MIM Capacitor (1.5 fF/um ²), DMOS
	Core (I/O) Voltage = 1.8 (3.3) V
SOI wafer	Diameter: 200 mm
	Top Si : Cz, ~18 Ω -cm, p-type, ~40 nm thick
	Buried Oxide: 200 nm thick
	Handle wafer: Cz(n) ~700 Ω-cm,
	FZ(n) ~7 kΩ-cm, FZ(p) ~40 kΩ-cm
Backside	Mechanical Grind, Chemical Etching, Back side Implant,
	Laser Annealing and Al plating



Analog Signal Readout Circuit



Design Specification of XRPIX3b

<u>Components</u>

- Chip Size : 2.9 mm sq. (Effective Area : 1.0 mm sq.)
- Pixel Size : 30 um sq.
- # of Pixel : 32 x 32 (= 1,024)

-> SF : 32 x 16 (Left) , CSA : 32 x 16 (Right)

Modification of XRPIX3 which is first prototype of XRPIX CSA circuit. Comparison of SF and CSA pixel. (Fabricated Jun, 2014)



Spectra of XRPIX3b



X-ray Mirror and Camera







http://astro-h.isas.jaxa.jp/diary/1329/ https://user.spring8.or.jp/sp8info/?p=2925

Plan for Satellite Mission

