PF BL-14A, BL-14B, BL-14C1/2011G658

X-ray application of next-generation image sensors using SOI technology

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Introduction

The SOIPIX group is developing monolithic pixel sensors using SOI technology. The development project has started as an important subject in KEK Development and Technology Project (KEK-DTP). The sensors were evaluated with monochromatic X-rays at KEK-PF beamlines, PF BL-14A, BL-14B, and BL-14C1. This document describes a part of the experimental results.

Experimental Summary

The experiment was done in 3 beamlines in FY2011. The summary is shown in Table 1. In PF BL-14A, wide ranges of X-ray energy are available for various X-ray detector tests and therefore it was used for sensor gain and quantum efficiency (QE) measurement. In PF BL-14B, uniform beams in medium X-ray energy (10-17 keV) are available and thus it was used for demonstrations of the phase-contrast imaging and evaluation of the spatial resolution. In BL-14C1, uniform X-ray beams in high energy (25-40 keV) is available and so it was used for tests of the refraction-contrast and absorption-contrast imaging. The SOI sensors were compared with commercial X-ray CCD.

Table 1: Experiment summary

Beam line	Beam time [year/month]	Beam Energy [keV]	Subjects
14A	2011/11	17.5	Sensor gain, QE
14A	2012/2	6	Sensor gain, QE
14B	2011/10	16	Imaging
14C1	2011/11	33.1	Imaging

SOI image sensor chips and its performance

SOI image sensors were developed within multi-project wafer (MPW) runs every year in which various LSI designs were gathered in a common process mask [1]. Therefore, various SOI image sensors have been used in several beam times since 2009 [2]. In FY2011, we used the integration-type pixel detectors, INTPIX3e, DIPIX, and INTPIX4. Float-Zone (FZ-) SOI pixel sensors were also tested and compared with the existing Czochralski-(CZ-) SOI pixel sensors. The pixel size of those detectors is between 14 and 17 microns. In the DIPIX sensors, some chips were thinned to 50 microns to study behaviours at the full depletion condition. Focused X-ray beams were irradiated to the sensors in the beam line 14A. The beam spot was set to 400 by 400 microns using a X-Y slit. The number of photons was counted by NaI detectors and SOI sensors to evaluate the quantum efficiency of SOI sensors. The back bias voltage was applied up to 100 V and the quantum efficiency was evaluated. The results are shown in Fig. 1. It was found that the sensor was fully depleted at 30 V. The stability of the quantum efficiency at more than 40 V is less than 10%. The absolute value of the efficiency is about 6.5%. The SOI sensors have 5 metal layers for the CMOS circuit and the total thickness of them is about 5 microns. Therefore, the effective thickness is about 45 microns and the absorption ratio of the silicon is consistent of the quantum efficiency of the thin-SOI sensors. A large-area integration-type image sensor (the pixel size 17 μm and 832 x 512 pixels), INTPIX4, and INTPIX3e were demonstrated in X-ray imaging. The analysis is underway.

Future Plan

We developed a larger area INTPIX and fine pixel INTPIX in FY2011. We will evaluate them to apply X-ray imaging experiment and time-resolved X-ray study.

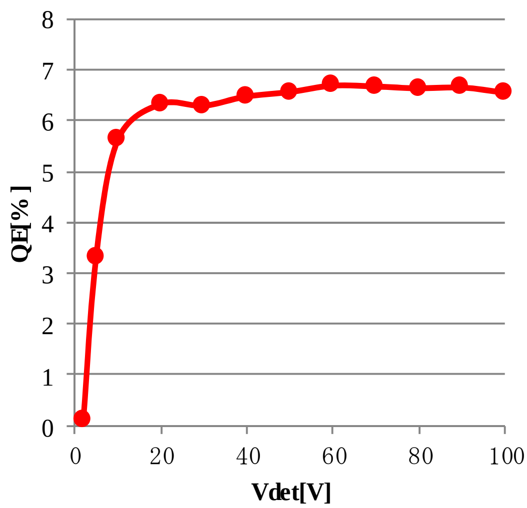

Fig.1 Dependence of quantum efficiency on back bias voltages of a 50 μm-thick SOI sensor with 17.5 keV monochromatic X-rays.

References

[1] T. Miyoshi et al., Nucl. Instr. And Meth. A, Vol. 636, Issue 1, Supplement 1, Pages S237-S241 (2011).
[2] T. Miyoshi et al., "Performance Study of Monolithic Pixel Detectors Fabricated with FD-SOI Technology", IEEE Nucl. Scien. Sympo. Conference Record, page 1704-1707, Valencia, Spain, Oct. 23-Oct.29 (2011).
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