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Comparison Between Bulk Micromachined and CMOS detectors for X-ray Measurements

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Summary: *This paper compares two x-ray detectors fabricated using two different technologies: one is based on a bulk micromachined silicon photodetector and the other is based on a standard CMOS photodetector. The working principle of the two detectors is similar: a scintillating layer of CsI:Tl is placed above the photodetector, so the x-rays are first converted into visible light (560 nm) which is then converted into an electrical signal by the photodetector. The different aspects of the fabrication and the experimental results of both x-ray detectors are presented and discussed.*

Keywords: *x-rays, scintillator*
Category: *4 (Non-magnetic physical sensors)*

1 Introduction

The two detectors reported and compared in this article are based on the same working principle: a scintillator material is placed above a photodetector. When the x-ray photons reach the scintillator, they are absorbed and converted into visible light. This visible light is then transformed into an electrical signal by the photodetector. One of the photodetectors is based on a sn-sub junction placed inside a bulk micromachined cavity [1]. The other one is based on a CMOS standard sn-sub junction [2].

2 Bulk micromachined x-ray detector

A cavity with 2 $mm \times 2$ mm square size and 400 μm depth is fabricated in a p-type silicon substrate using KOH etching. Inside the cavity, arsenic is implanted in order to form the sn-p junction of the photodiode. After that, the cavity is filled with a scintillating material (CsI:Tl) and finally, a reflective layer is placed above the scintillating material [1]. Figure 1 shows a schematic cross section of the device. Figure 2 shows a picture of the device before the placement of the scintillating material and the reflective layer.

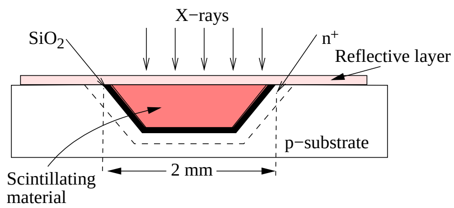

Fig. 1: Cross-section of the BMM x-ray detector.

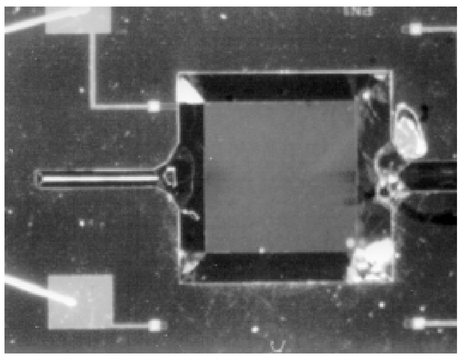

Fig. 2: Picture of the BMM x-ray detector before the placement of the CsI:Tl.

3 CMOS x-ray detector

The second device that is described here consists in four 400 $\mu m \times 400$ μm photodiodes fabricated in a standard CMOS process. In this case, an aluminum dye is used, where some cavities were opened. The cavities were then filled with a scintillator material and the set was placed above the CMOS photodetectors [2] as is shown in figure 3. Figure 4 shows a picture of the CMOS device before the placement of the aluminum dye with the scintillating material.

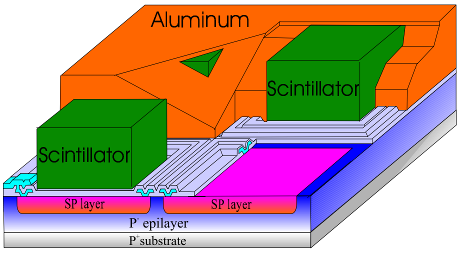

Fig. 3: Structure of a 2×2 CMOS x-ray detector array.

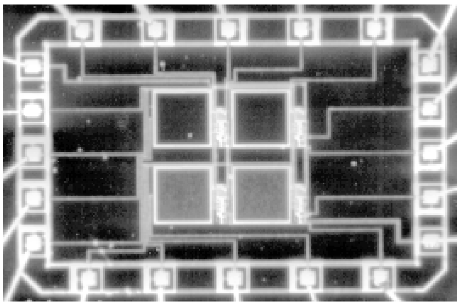

Fig. 4: Picture of the 2×2 CMOS photodetector array before the placement of the CsI:Tl layer.

4 Experimental results

The experiments on the two devices were performed using a didactic x-ray tube with a molybdenum anode from Leybold. In both cases, the tube was powered with a voltage of 35 kV and a current ranging to 1 mA. This tube produces x-rays whose energy peak is near 20 keV. The results of these measurements are shown in figure 5 for the BMM detector and in figure 6 for the CMOS detector.

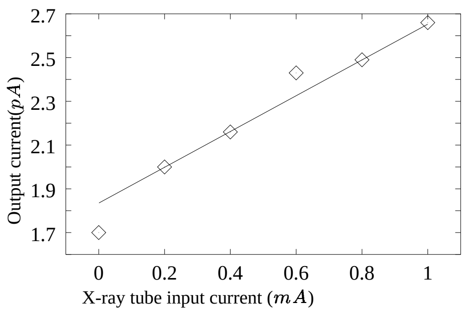

Fig. 5: Output current of the BMM x-ray detector with a x-ray tube input voltage of 35 kV.

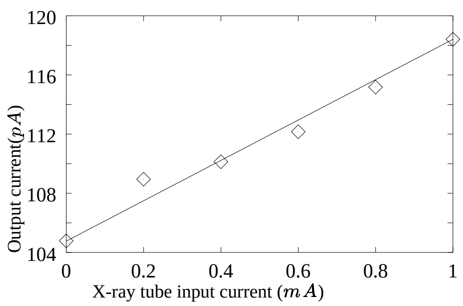

Fig. 6: Output current of the CMOS x-ray detector with a x-ray tube input voltage of 35 kV.

5 Comparison between the two x-ray detectors

- The BMM detector do not use a standard fabrication process in the photodetector construction. This fact permits the optimization of the junction depth in order to obtain a spectral response that matches the emission peak of the scintillator. Nevertheless the fabrication of the CMOS detector is cheaper as it make use of a standard fabrication process.

- The fabrication of the cavities in the BMM detector is easier due to the use of anisotropic chemical etching of the silicon instead of the mechanical methods used for the CMOS detector.

- The dimensions of the pixels in the CMOS detectors can be smaller than in the BMM one due to the fact that the side walls of the cavities fabricated with KOH etching in the BMM detector are not vertical (figure 1).

- Due to the standard fabrication of the CMOS prototype it is possible to integrate the electronics with the photodetectors without additional fabrication steps. This integration is more difficult in the BMM one.

- Both detector prototypes show a linear response up to 1 mA of x-ray tube input current (figures 5 and 6).

- The CMOS detector has a higher sensibility, but a larger offset (figure 6).

6 Conclusion

Two x-ray detector prototypes were fabricated using two different technologies, one is based on a bulk micromachined silicon photodetector and other is based on a standard CMOS photodetector. The fabrication process and the performance of the two prototypes were presented and discussed comparatively. Whereas the CMOS detector has advantages in the integration of the photodetectors with the electronics and the detection sensibility, the BMM detector shows advantages in the fabrication of the cavities and the lower offset.

References

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