# TlBr X-ray Imager with Photon-Charge Count Type Readout ASIC Compare with CdTe Image

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**ABSTRACT**

*X-ray imaging are widely used in various applications, however, conventional films and imagers cannot obtain information about the energy of X-ray photons, and the energy sensitivity curve is constant for each individual patient, so the imaging conditions for obtaining images that are easier for the human eye to see have been obtained through the experience and intuition of technologists. The photon counting imager can obtain photon energy information, and we will discuss the effect of photon energy on image quality in converting invisible light images to visible images.*

## 1 Direct Conversion X-ray imager

X-ray imaging has long been used in a wide range of useful applications as invisible light imaging. Generally, X-ray films and imaging plates (IPs) are widely used, but in recent years, digital radiography (DR) imagers, which can output X-ray images directly as electrical signals, have become popular. However, these are generally referred to as indirect-conversion X-ray imagers, which convert X-rays to visible light and then use a visible-light imaging device to image this visible light. The scintillator is generally about a millimeter thick because of the high penetrating power of X-rays. Therefore, light diffuses within this scintillator layer, and in principle, blurring occurs. On the other hand, we have been studying the direct conversion type, which uses a semiconductor instead of a scintillator to directly convert light into an electric charge without converting it into visible light, and have already reported its high resolution and high contrast characteristics. We have been working on direct-conversion X-ray imagers using CdTe and CdZnTe for medical, non-destructive testing, and security applications at energies ranging from tens to hundreds of keV, and we are now working on an imager using TlBr, which has even higher sensitivity at higher energies in response to recent demand for high-energy X-ray imaging. We are now working on an imager using TlBr, which has even higher sensitivity at higher energy.

## 2 Energy response characteristics of imager for X-ray imaging

The reason why we have been working on a new direct-conversion X-ray imager using TlBr is that the energy sensitivity property of TlBr is higher at high energy than that of CdTe. Figure 1 Test charts imaged with different semiconductors

As shown in Figure 1, the developed TlBr imager exhibited resolution (spatial resolution) equivalent to that of CdTe. However, the contrast was higher for CdTe. This is thought to be because high-energy X-rays penetrating the Pb portion of the chart were detected more in the high-energy sensitive TlBr imager than in the CdTe imager, resulting in the appearance of white highlights in the image. The difficulty of color filtering in visible light, especially energy low-pass filtering, may cause the high-sensitivity imager to have the opposite effect, so the current situation relies on the skill of the radiologist.

## 3 Photon-charge counting imaging and energy spectrum imaging

Figure 2 shows a block diagram of photon and charge counting. This readout signal processing ASIC can not only count the number of photons, but can also determine the energy of each photon, i.e., the energy of each incident X-ray photon, and by forming a histogram, can obtain the energy spectrum for each pixel and frame. Thus, multi-energy X-ray imaging with energy discrimination is possible.

The reported photon-charge counting signal processing allows free design of this energy filter and free variation of the energy response curve. Therefore, the high sensitivity in the high-energy band expected of TlBr and the imaging without the sensitivity "blurring" due to the K absorption edge in the low-energy band can be achieved for various subjects.

## 4 TlBr X-ray imager

Fig. 3 shows a structural diagram of the TlBr X-ray imager module with TlBr and our photon-charge counting type ASIC. TlBr has common Tl electrode at top side and has no electrode at bottom side. At the bottom-side, Agbumps were builded as connection material and pixel electrodes. Therefore, the device structure is Tl / TlBr/ Ag / ASIC. Then, this device was put on the PCB board for readout and data transfer of the signal from ASIC(LSI), and X-ray was irradiated from top-side through some object.

The X-ray imaging was carried out in Fig. 4 with (a)(b) no object, (c)thin Cu/Solder object of character 「イ」 and (d) thick Pb「イ」object by 150kV, 500μA acerated micro-forces X-ray generation unit. In the TlBr case, very low contract image of 「イ」 with thin Cu/Solder object even if it was clearly found by using CdTe imager. This is because that TlBr X-ray imager has high sensitivity in high-energy region, so thin Cu/Solder object was penetrated by high-energy X-ray and TlBr imager more detected the high-energy (low attenuated) energy X-ray than CdTe imager. Therefore, very clear 「イ」image could be detected by TlBr imger by using thick PB「イ」object.

Finally, MTF measurement results were compared with TlBr and CdTe X-ray imagers. In Fig. 5, the MTF value is almost same between TlBr and CdTe, and they were shown so high value near the theoretical value. Both imagers have good resolution by direct conversation of X-ray photons to charges.

## 5 Conclusion

TlBr X-ray imager with photon-charge counting read-out IC (ASIC) was developed like as CdTe X-ray imager. Both imagers showed high MTF (high-resolution and high-contrast), but the optimal objects were different by the sensitively response with X-ray photon energy. It is expected that each will be used in different ways to take advantage of their respective features.

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## Figures

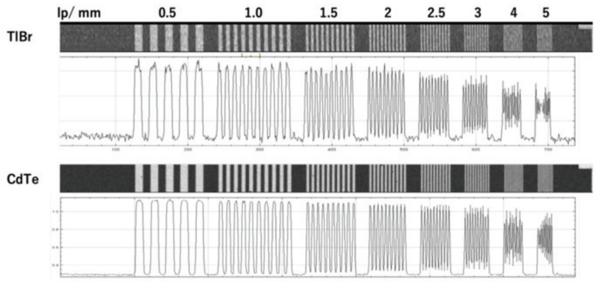


Fig. 1 X-ray image and line profile of X-ray test imaging chart by TlBr imager and CdTe imager

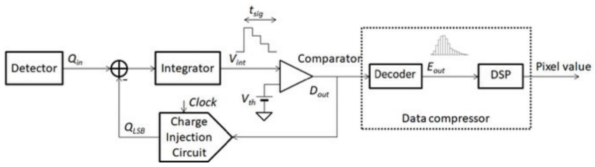


Fig. 2 Schematic diagram of Photon-Charge count circuit in readout signal processing ASIC.

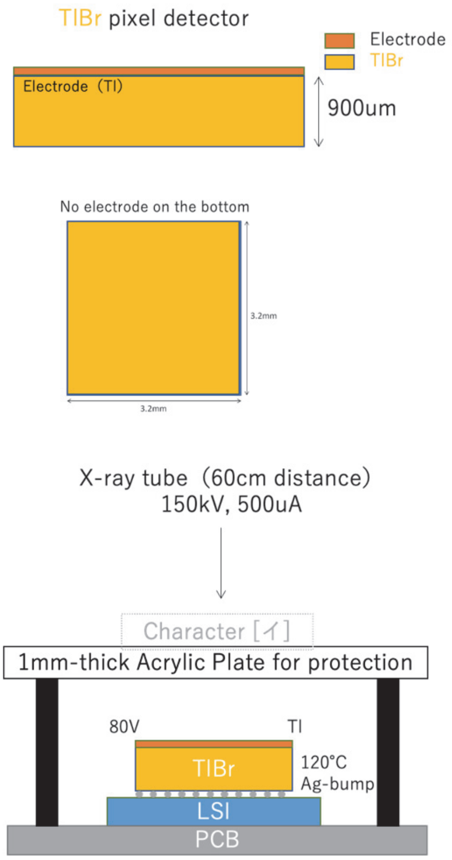


Fig. 3 Schematic diadgram of TlBr pixel detector module and X-ray imaging measurement.

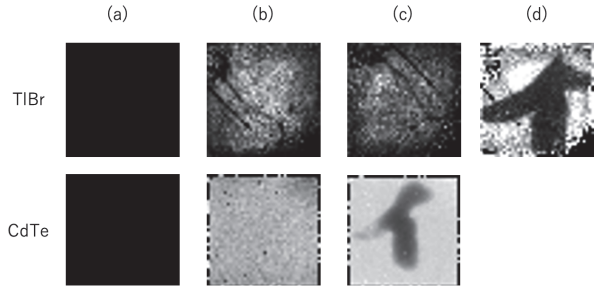


Fig. 4 X-ray imaging pictures by TlBr and CdTe X-ray imager; (a) Background(no X-rays), (b) X-ray only w/o objects, (c) X-ray images with thin Cu/Solder and (d) X-ray images with thick Pb object.

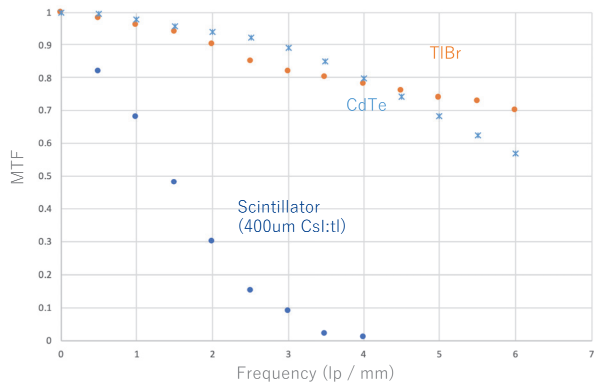


Fig. 5 MTF of TlBr, CdTe and Scintillator X-ray imager by knife-edge method