Study on Characteristic difference of Semiconductor Radiation Detectors fabricated with a wet coating process

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Abstract : The wet coating process could easily be made from large area film with printing paste mixed with semiconductor and binder material at room temperature. Semiconductor film fabricated about 25mm thickness was evaluated by field emissions-canning electron microscopy (FE-SEM). X-ray performance data such as dark current, sensitivity and signal to noise ratio (SNR) were evaluated. The HgI_2 semiconductor was shown in much lower dark current than the others, but the best sensitivity. In this paper, reactivity and combination character of semiconductor and binder material that affect electrical and X-ray detection properties would prove out though experimental results.

Keywords : Semiconductor, HgI_2 (mercuric iodide), PbO (lead oxide), PbI_2 (lead iodide), CdTe (cadmium tellurium)

Introduction

Some semiconductor materials can be used as radiation imaging detectors in a variety of medical field. Promising candidate materials are high-gain conversion materials such as mercuric iodide (HgI_2) [1], lead iodide (PbI_2) [2], lead oxide (PbO) [3] and cadmium telluride (CdTe) [4], etc. Usually, they are deposited by physical vapor deposition (PVD) processes [2]. The problems such as poor film quality, unstable electrical operation and the difficult of large area deposition have been reported even if these processes have excellent x-ray sensitivity [5].

For fabricating with large area X-ray detector, screen printing method has reported recently [5]. This paper presents the primary experimental results of the semiconductor radiation detectors derived by a novel wet coating process for large area x-ray imaging. In this paper, reactivity and combination character of semiconductor and binder material that affect electrical and X-ray detection properties would prove out though experimental results.

Experimental Procedure

Semiconductor materials used for experiments were mercuric iodide (HgI_2), lead iodide (PbI_2), lead oxide (PbO) and cadmium telluride (CdTe), respectively. And adhesive solution was formed by mixing poly-vinyl-butral (Acros Organics Corporation) in moderate solution. The special paste was made from semiconductor materials and the adhesive solution. The thick semiconductor radiation films were deposited by a novel wet coating method. For the morphologic observation of the fabricated films, field emission-scanning electron microscopy was used (Hitachi S-4300SE). To compare the electrical characteristics, the dark current and the x-ray sensitivity were measured. An electrometer (keithley 6517A) was connected to a power supply (DEI PVX-4110) for the dark current measurement. For x-ray sensitivity measurement, a diagnostic x-ray generator (Toshiba TF-10ML-2) and an oscilloscope (LeCroy 62XI) were used. And x-ray exposure condition was 80kVp, 100mA, and 0.03 second. And signal to noise to ratio (SNR) could be calculated by relative ratio of signal charge and dark current.

Results and Discussion

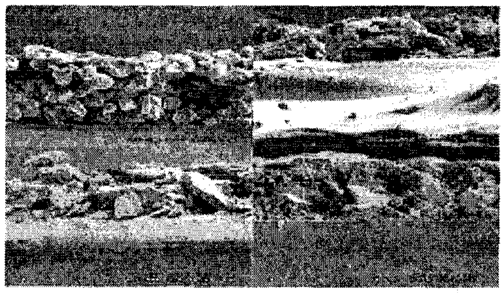

Figure 1 Cross-sectional images of a) HgI_2, b) PbO, c) PbI_2, and d) CdTe film deposited by a special wet coating method

The morphologies of the various semiconductor films derived by our method were observed by scanning electron microscopy analysis. Figure 1 shows the cross-sectional images of the thick films of HgI_2, PbO, PbI_2 and CdTe, which were deposited with our wet coating process, respectively. As shown in images, the uniformly excellent particles were only observed in the HgI_2 film, while the others showed a poor film quality with significant vacancy. It is thought that the HgI_2 film had become high density because HgI_2 which has a solvent became small grain size.

The electrical characteristics of the semiconductor detectors were compared with the dark current, the x-ray sensitivity and signal to noise ratio.

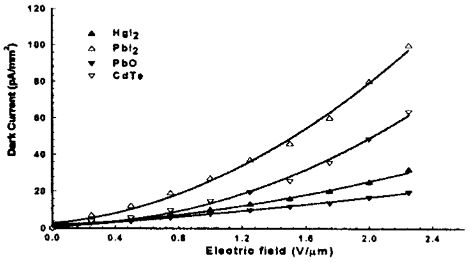

Figure 2 The dark currents of a) HgI_2, b) PbO, c) PbI_2 and d) CdTe film as a function of an electric field

Figure 2 shows the measured dark current of the deposited films as a function of an electric field. The dark current increased with an electric field monotonically from 0 to 2.3 V/μm. And the dark current of the HgI_2 and the PbO are lower value than 10pA/mm^2 at 1 V/μm required in common medical imaging applications [6].

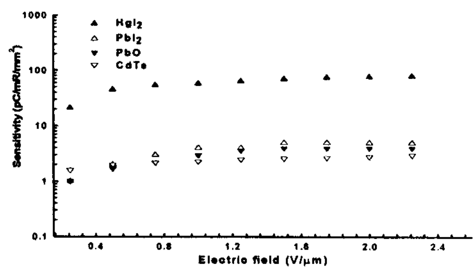

Figure 3 The x-ray sensitivity of a) HgI_2, b) PbO, c) PbI_2, and d) CdTe film as a function of an electric field

Figure 3 shows the measured x-ray sensitivity of the various semiconductor films as a function of an electric field. Although its trends were different from the dark current, the x-ray sensitivity also increased with an electric field. As shown in Figure 3, the x-ray sensitivity of the HgI_2 is superior, while the others are a very low values.

Figure 4 shows the signal to noise ratio of the semiconductor radiation detectors as a function of an electric field. Although it has been reported that the dark current and the x-ray sensitivity of thermally evaporated semiconductor detectors such as the HgI_2, PbO, PbI_2 and CdTe is likely same, as shown in figure 4, the SNR of the HgI_2 provides higher value than the others [1-4]. These results are due to inherent reaction of HgI_2 with the special binder solution.

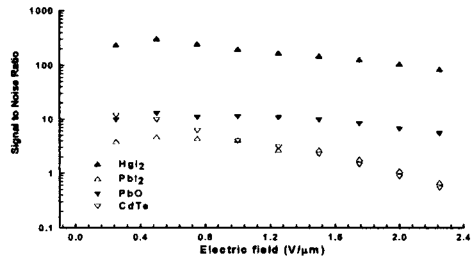

Figure 4 Signal to noise ratio of a) HgI_2, b) PbO, c) PbI_2, and d) CdTe film as a function of an electric field

Conclusions

We compared to the electrical properties with the semiconductor radiation detectors that were deposited with a novel wet coating method. The uniformly excellent particles were only observed in the HgI_2 film, while the others showed a poor film quality with significant vacancy. The dark current increased with an electric field monotonically and the dark current of the HgI_2 and the PbO are lower value than 10pA/mm^2 at 1 V/μm required in common medical imaging applications. The signal to noise ratio of the HgI_2 provided higher value than the others because of to inherent reaction of HgI_2 with the special binder solution used in our coating method. In this work, we could demonstrate that our special coating method will provide a possibility for large area x-ray imaging detector

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