X-ray Response Characteristic of Zn in the Polycrystalline $Cd_{1-x}Zn_xTe$ Detector for Digital Radiography

Sang-Sik Kang
Department of Biomedical Engineering, College of Biomedical Science and Engineering, Inje University, Kimhae, Kyungnam 621-749, Korea

Jae-Hyung Kim, Hyung-Won Lee, Chi-Woong Mun, and Sang-Hee Nam*
Medical Imaging Research Center, Inje University, Kimhae, Kyungnam 621-749, Korea

E-mail : nsh@bme.inje.ac.kr

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The $Cd_{1-x}Zn_xTe$ film was fabricated by thermal evaporation for the flat-panel X-ray detector. The stoichimetric ratio and the crystal structure of a polycrystalline $Cd_{1-x}Zn_xTe$ film were investigated by EPMA and XRD, respectively. The leakage current and X-ray sensitivity of the fabricated films were measured to analyze the X-ray response characteristic of Zn in the polycrystalline CdZnTe thin film. The leakage current and the output charge density of $Cd_{0.7}Zn_{0.3}Te$ thin film were measured to 0.37 nA/cm^2 and 260 pC/cm^2 at an applied voltage of 2.5 V/㎛, respectively. Experimental results showed that the increase of Zn doping rates in $Cd_{1-x}Zn_xTe$ detectors reduced the leakage current and improved the signal to noise ratio significantly.

Keywords: CdZnTe detectors, Digital radiography, Leakage current, X-ray sensitivity

1. INTRODUCTION

In recent years, a flat-panel digital imaging detector ıas been developed for digital radiography application 1-3]. Digital radiography has many advantages over :onventional radiography, such as a high dynamic range, ast imaging acquisition and display, digital archiving nd retrieval systems, teleradiology, display of a stored mage without degradation, extended capabilities of data nalysis and image processing, and a reduction in patient losages. These systems are composed of an active-natrix TFT (thin film transistor) array. Currently, two ypes of detection principles have been realized in digital adiography[3]. One is an indirect detection type and the ›ther a direct detection type. In the indirect detection ype, absorbed X-ray photons are converted to visible ight in a phosphor layer, and the visible light is then :onverted to an electrical signal by a two-dimensional ›hotodiode array. In direct detection type, absorbed X-ay photons are directly converted to electron-hole pairs n a conversion layer, and then collected as electric :harges on storage capacitors via an electric field. In ;eneral, the direct detection type, in which a-Se amorphous Se) is most commonly used as a conversion ayer, provides an excellent spatial resolution because of its simple conversion process. However, it suffers 1 low X-ray sensitivity because it has a low X stopping power and a high generation energy of abou eV per electron hole pair. Moreover, a-Se has advantages, such as the breakdown of the TFT array a extremely high voltage of above 10 V/㎛, nar several kV, for collecting charges.

Accordingly, a new approach has been carried ou investigate new conversion materials[4]. Candi materials are lead iodide (PbI_2), mercury iodide (H thallium bromide (TlBr), and Cadmium telluride (Cd These materials have both inherently high stop power and wide band gap energy[3]. Among these (Zn)Te film has sufficient stopping power for use a X-ray converter, and it is more stable, both mechani and chemically, than other high-gain materials. On other hand, CdTe which has long been used as a γ detector has a disadvantage as an X-ray image dete because of its high leakage current.

Specifically, the resistivity is greatly increase doping Zn in CdTe film[5]. This high resistivity is du the wide band gap of this ternary semiconductor w results in low leakage currents and, consequently, noise characteristics. $Cd_{1-x}Zn_xTe$ detector is a potent interesting material for digital radiography[6-8] bec ıs high stopping power, high mass density (5.8g/cm^3) an effective atomic number Z of 49.9 ($Cd_{0.9}$:48, ı:30, Te:52). This would allow a decrease in detector kness and, consequently, good spatial resolution.

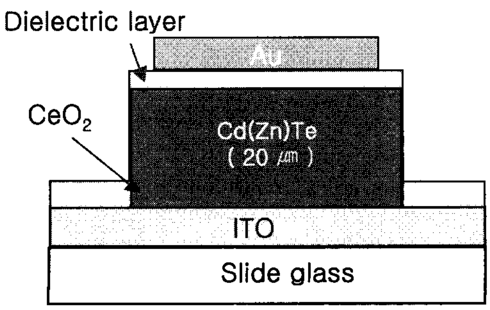
ı this paper, the leakage currents and X-ray ;itivity in the polycrystalline $Cd_{1-x}Zn_xTe$ detectors are sured as a function of an applied voltage to ;stigate X-ray response characteristics for digital ography. Experimental results showed that the ease of Zn doping rates in the $Cd_{1-x}Zn_xTe$ detector ıced the leakage current and improved the signal to ,e ratio significantly.

2. EXPERIMENTAL

Stoichimetric ratio and x-ray diffraction of Cd_{1-x}-Zn_xTe thin film

'he $Cd_{1-x}Zn_xTe$ film was produced by thermal eva-ıtion for a flat-panel X-ray detector. The starting erials were prepared by mixing CdTe (99.999%) and '99.999%) in a stoichimetric ratio of x = 0, 0.15, .025,). Prior to $Cd_{1-x}Zn_xTe$ depositioning, the ITO glass rning glass, 2× 5 cm^2) was washed by aceton and, ı methane, followed by a DI water rinse and, finally vn dry in N_2. The polycrystalline Cd (Zn)Te films e produced on an indium-tin-oxide (ITO) coated ,s substrate by thermal evaporation. Cd (Zn)Te films e deposited at room temperature, and the deposited ı thickness was 20 ㎛. The Au layer with an area of ‹ 1.5 cm^2 was evaporated as a upper electrode after ting the dielectric layer on the $Cd_{1-x}Zn_xTe$ film by ;2060 (SCS, USA). The dielectric layer was osited to prevent the hole injection from the top :trode to $Cd_{1-x}Zn_xTe$ layer. Fig. 1 illustrates the ɜmatic cross section of fabricated polycrystalline Cd)Te film.

'he stoichimetric ratio of Cd/Zn/Te was investigated the Electron Probe Micro Analyzer (EPMA-1400, nadzu, Japan) for quantitative analysis. X-ray diffraction



1 Schematic of fabricated polycrystalline CdZnTe film.

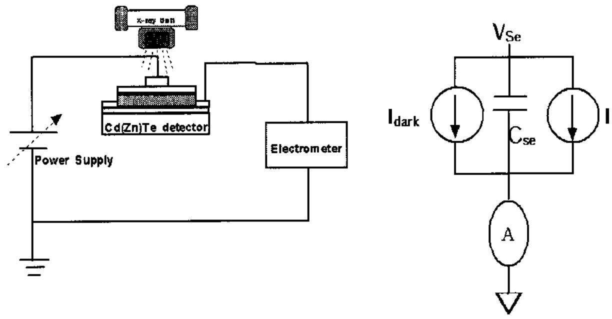


Fig. 2. Schematic diagram for electrical measuremen of Cd(Zn)Te detector.

was carried out to investigate the crystal structure of th $Cd_{1-x}Zn_xTe$ film using XRD (RAD-3C, Rigakı Japan)[9].

2.2 Electrical measurement

Figure 2 shows an experimental schematic for leakag currents and X-ray sensitivity measurements. I-\ characteristics of $Cd_{1-x}Zn_xTe$ film were measured tı investigate the electrical properties. Leakage current flowing in Cd (Zn)Te film were measured in a dark stat after applying voltage at an interval of 0.5 V/㎛ fror 0.5 to 2.5 V/㎛. The experimental setup for measurin the leakage currents was composed of a DC powe supplier (3033B, Protek) for applying voltage, and a electrometer (6517A, Keithley, USA).

The measurement of X-ray sensitivity is similar to th measurement of leakage current. The x-ray generatc used in this study was a Shimadzu TR-500-12 Irradiation conditions for signal acquisition were 50 kV 150 mA, and 0.1 s. The radiation dose was monitored b an Ion Chamber 2060 (Radical Cooperation, USA during experimentation.

3. RESULTS AND DISCUSSION

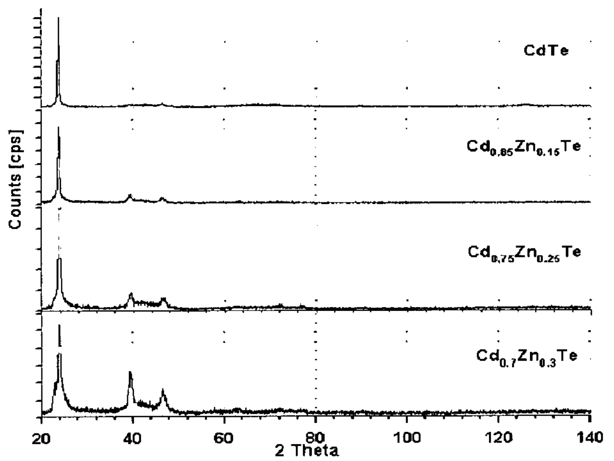
3.1 Stoichimetric ratio and x-ray diffraction

The Stoichimetric composition of $Cd_{1-x}Zn_xTe$ thin filr was summarized in Table 1. As is well known, eve small stoichimetric deviations can produce larg variation in intrinsic defect concentrations. Th stoichimetric fabrications of Cd/Zn/Te film affect ɛ lectrical characteristics significantly. Compared to th component of Cd, excess Te and Zn are observed i evaporated film regardless of the concentration of Zı These results can then be analyzed with the absorptio coefficient of the substrate and the partial pressure of C‹ Zn and Te.

Figure 3 shows the XRD pattern of a polycrystallin and $Cd_{1-x}Zn_xTe$ (x = 0, 0.15, 0.25, 0.3) as a function of liffraction angle of 2θ . As shown in Fig. 3, a strong)eak was observed at around 24° in thermally eva-)orated CdTe thin film. As Zn was progressively ;ubstituted with Cd in the CdTe, the peaks increased at I0 and 46 degrees, whereas the peak at 24 degrees was elatively small.

[able 1. Composition of $Cd_{1-x}Zn_xTe$ thin films.

Composition of Raw Materials	Cd : Zn : Te[atomic %]
CdTe	46.73 : 0.03 : 53.24
$Cd_{0.85}Zn_{0.15}Te$	36.20 : 9.61 : 54.19
$Cd_{0.75}Zn_{0.25}Te$	31.53 : 14.40 : 54.07
$Cd_{0.70}Zn_{0.30}Te$	28.26 : 18.63 : 53.11



;ig. 3. X-ray diffraction pattern.

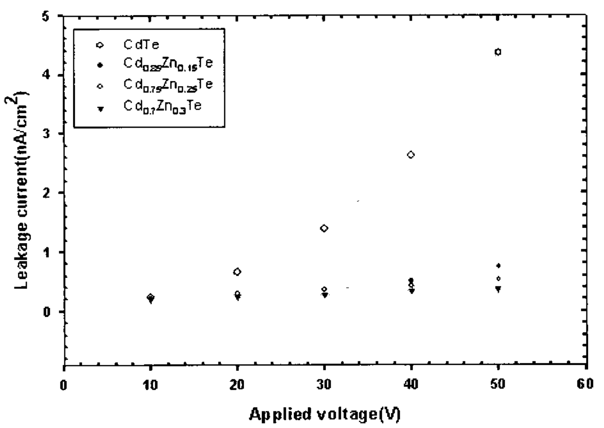


Fig. 4. Leakage current as a function of applied voltage.

3.2 Leakage current

Figure 4 shows the leakage current of $Cd_{1-x}Zn_xTe$ as a function of applied voltage. The measured leal current was drastically decreased by doping Zn aton the CdTe film. In applied voltage of 50 V, leal current was 4.35 nA/cm^2 for CdTe and 0.4 nA/cm $Cd_{0.85}Zn_{0.15}Te$, respectively. These results show thai introduction of Zn in the CdTe induces an increase o energy band gap due to an upward shift of conduction band edge[10]. The wider band gap incre resistivity and then decreases the leakage current.

3.3 X-ray sensitivity

Figure 5 shows the output charge density of $Cd_{1-x}Z$ (x = 0, 0.15, 0.25, 0.3) film. The output charge der

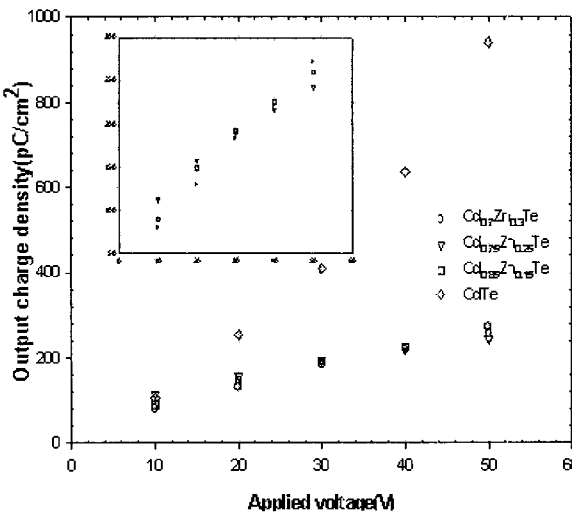


Fig. 5. Output charge density as a function of applied volta

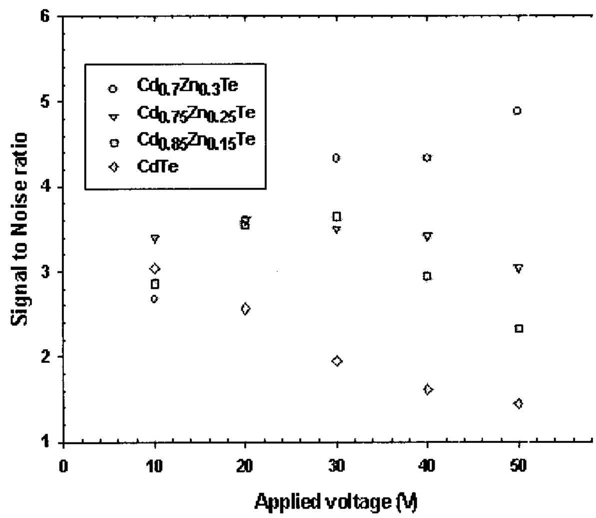


Fig. 6. Signal to noise ratio as a function of applied voltag

layed similar behavior compared with the leakage ents for all samples. Figure 6 shows the signal to e ratio of $Cd_{1-x}Zn_xTe$ (x = 0, 0.15, 0.25, 0.3) film as a :tion of applied voltage. Experimental results show the increase of Zn doping rates in $Cd_{1-x}Zn_xTe$ film iciently suppresses a leakage current and improves a signal to noise ratio significantly. The $Cd_{0.7}Zn_{0.3}Te$ having a leakage current of 0.37 nA/cm^2 and an ›ut charge density of 260 pC/cm^2 shows the highest .e, of 4.66 at an applied voltage of 50V, among all ples.

4. CONCLUSION

polycrystalline $Cd_{1-x}Zn_xTe$ film for digital radio- ›hy is fabricated by thermal evaporation. The stoichi- ric ratio and crystal structure of the fabricated Zn/Te film was analyzed by EPMA and XRD. The ication of Cd(Zn)Te film by thermal evaporation has ıy industrial and medical applications because a large panel detector can be realized at a low expense. n measurements both leakage current and X-ray ;itivity, it was verified that the increase of Zn :tion rates in $Cd_{1-x}Zn_xTe$ film sufficiently suppresses eakage current and improves X-ray sensitivity ificantly. $Cd_{0.7}Zn_{0.3}Te$ film with a leakage current of ' nA/cm^2 and an output charge density of 260 pC/cm^2 vs the highest SNR, at 4.66, among all samples. Our ɜrimental result offers potential capability for arch and evaluation of digital X-ray image detectors g $Cd_{1-x}Zn_xTe$ thin film.

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