The Measurement and Evaluation of X-ray Characteristics of Cadmium Sulfide as a Multi-function Dosimeter

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To evaluate the performance of cadmium sulfide as a multi-function X-ray dosimeter, we made an X-ray detector that was based on cadmium sulfide using evaporation technology, and measured its response to X-ray exposure. The voltages of cadmium sulfide were measured on the various X-ray tube potentials, X-ray tube currents and exposure times. The regression analysis of the voltage response of CdS on the tube-potential variation was y=0.0995x-0.1146 (R^2=0.9595, σ=0.08, standard error=2%) and the regression analysis of the voltage response of CdS on the tube-potential variation was y=0.0439x+1.1891. (R^2=0.9021, σ=0.04, standard error=1.8%) The regression analysis of the voltage response of CdS on the X-ray exposure time variation was y=8.2853x+5.5878 (R^2=0.7287, σ=0.06, standard error=1.9%). In conclusion, cadmium sulfide responded linearly to the variation X-ray conditions, suggesting cadmium sulfide to be a feasible X-ray sensor of multi-function dosimeter related instruments.

Key Words: X-ray, Cadmium Sulfide, Dosimeter

INTRODUCTION

A solid conductive dosimeter is based on the effect of electron-hole production under the radiation exposure. These dosimeters use Se, Si, Ge and CdS materials. According to the paper, CdS is manufactured easily and shows high light absorption efficiency.[1-4] CdS is based on the photoconductive effect. CdS is usually utilized as electronic parts such as a relay and a camera exposure device. In this study, we developed a multi-functional X-ray dosimeter using CdS's bulk properties.[5, 6]

Conventionally, the quality of X-ray device is evaluated using kVp meter and mAs meter. To evaluate mAs, usually mAs meter should be connected directly to high power transformer.[7] It is a dangerous work. So, there need a easier X-ray dosimeter. In this paper, the measurements of the voltage responses of CdS to X-ray exposure were performed to evaluate it's performance and feasibility as an multi-function X-ray dosimeter.

MATERIALS AND METHODS

We manufactured a CdS sensor using a resistive heating evaporation method. At a slide glass is washed and Al substrate is evaporated next. And CdS/SnO_2 was evaporated over Al substrate. Au was evaporated as top electrode. The size of CdS sensor is 2 cm by 2 cm, and thickness of sensor is 300 nm. Fig. 1 shows the procedure of CdS evaporation. Fig. 2 shows the surface of CdS sensor by SEM. The shown white spots are particles caused by a heat boat.

Fig. 3 is a schematic diagram of experiment system. Fabricated CdS sensor was placed in dark-box and then is exposed to X-ray. During the X-ray exposure, we measured voltage variations of CdS sensor. These data are transmitted to oscilloscope LM 500 MHz (Lecroy,

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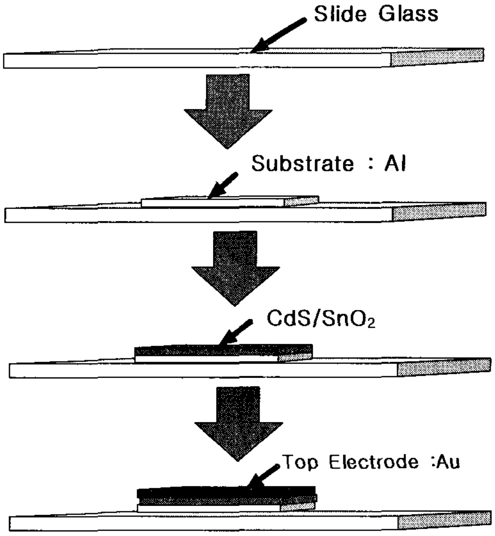

Fig. 1. Flowchart of CdS evaporation.

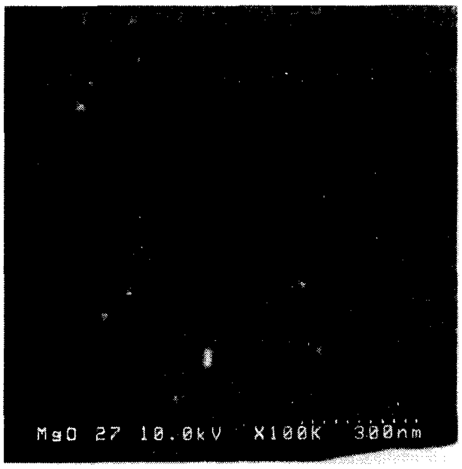

Fig. 2. A picture of evaporated CdS cell surface observed by SEM.

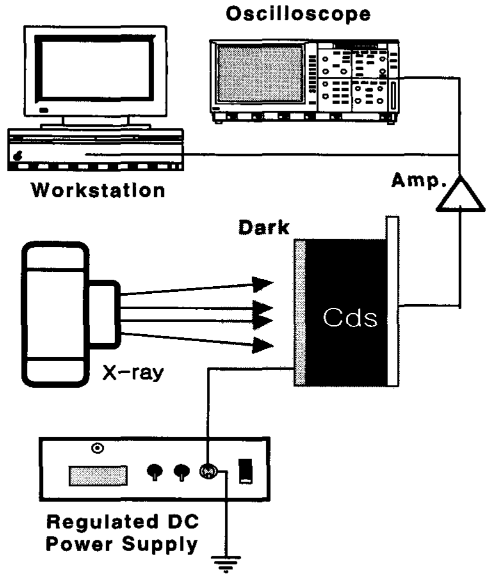

Fig. 3. A schematic diagram of the experimental system.

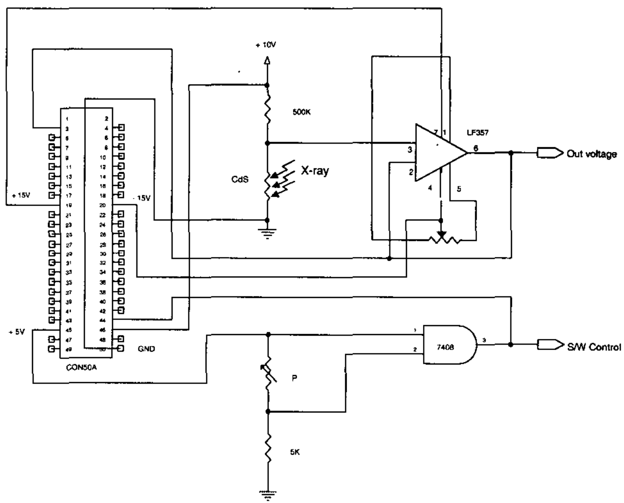

Fig. 4. Circuit of CdS experiment.

USA) and analog-to-digital converter AX5412 (AXIOM, USA) through buffer. CdS sensor and commercially available X-ray generator TR-500-125 Radio-Tex Cx-S (Shimadzu, Japan) were used for this experiment. A circuit diagram of driving part of CdS sensor is shown in Fig. 4. For the data acquisition, OP-amp LF357 (National Instrument, USA) which had a high input impedance, a low input bias current and a wide frequency bandwidth were used.

In circuit design, ADC supplies all bias of circuit except external CdS sensor. Supplied bias of CdS is 10 V. a piezoelectric sensor is connected to X-ray exposure switch in order to obtain the synchronous signals from CdS sensor to X-ray exposure. When X-ray exposure switch is turned on, a piezoelectric sensor generates a start of conversion (SOC) signal of ADC. Then the output signals of CdS are measured. A start of conversion signal from a piezoelectric sensor was transmitted to 44th pin of ADC. The voltage variation of CdS sensor were measured at the moment of X-ray exposure. Software for the data acquisition and storage were made using C-language.

First, it measured repeatedly the voltage response of

CdS sensor to the various tube potentials from 40 kVp to 100 kVp with a increacement of 10 kVp step under the fixed condition as the X-ray tube current products exposure time(mAs) with 100 mA tube current and 0.2 sec exposure time. Second, it is measured repeatedly the voltage response of CdS sensor according to the variations of X-ray tube current (mA) variations. The measured mA data are 40, 50, 63, 80, 100, 120, 160, 200, 320 mA. Third, it measured repeatedly the voltage response of CdS sensor according to the variations of X-ray exposure time (s) variations. The measured exposure time data are 0.04, 0.08, 0.12, 0.20, 0.25, 0.30 s.

RESULTS AND DISCUSSIONS

1. Response of CdS sensor with respect to the X-ray tube potential (kVp) variations

Fig. 5 shows the voltage response of CdS sensor to the variations of X-ray tube potential. The voltage response of CdS sensor is larger as the tube potensial is larger. The voltage responses of CdS sensor increases according to the increasing X-ray tube-potential

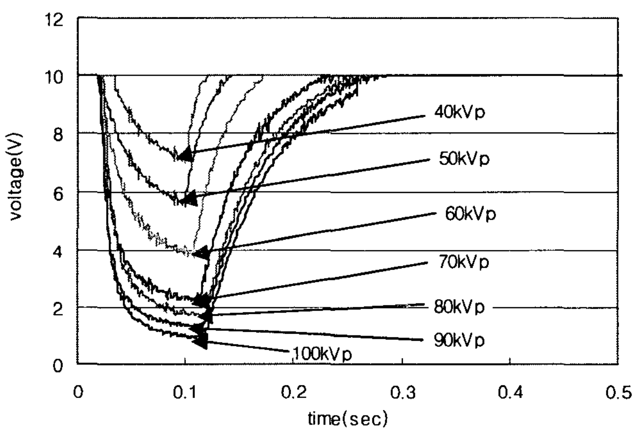

Fig. 5. The response of CdS sensor according to the various X-ray tube potentials from 40 kVp to 100 kVp with the 10 kVp step.

Table 1. Standard deviation of the CdS voltage response for the tube potentials of 40, 50, 60, 70, 80, 90 and 100 kVp

KVp	40	50	60	70	80	90	100
Std. Deviation	0.01	0.02	0.09	0.15	0.16	0.13	0.02

from 40 kVp to 100 kVp with 10 kVp step. Also we calculated the standard deviation (Table 1) and investigated the properties of stability and reappearance. CdS sensor, included in II-VI semiconductor group,[4, 8-9] generates output voltages as a response to X-ray exposure conditions.

As a result of Table 1, the standard deviation values of X-ray exposure conditions, 60-90 kVp, are larger than that of 40, 50, 100 kVp conditions. Small value of standard deviation means that it is tend to be good characteristics of reproducibility and stability. When the out voltage of CdS sensor was small, standard deviation values were small because of classification difficulty between signal and noise. When responses of CdS sensor are large, standard deviation values were small because some amount of X-ray was transmitted through the sample.[7-10] The standard deviation had large value under the conditions of the tube potential in the range of 60-90 kVp. This increasing variation results from the electronic components and high power noise.[2, 10] Relationship between X-ray tube potential variation and response signal was analyzed using a linear regression method (Fig. 6). It shows the linear characteristics ($y=0.0995x-0.1146$, $R^2=0.9595$). According to Fig. 6, This value is not absolute value. Because the detection value of X-ray dose is not absolute but relative[7, 10, 11]. This point is very important for the design of multi-function dosimeter.

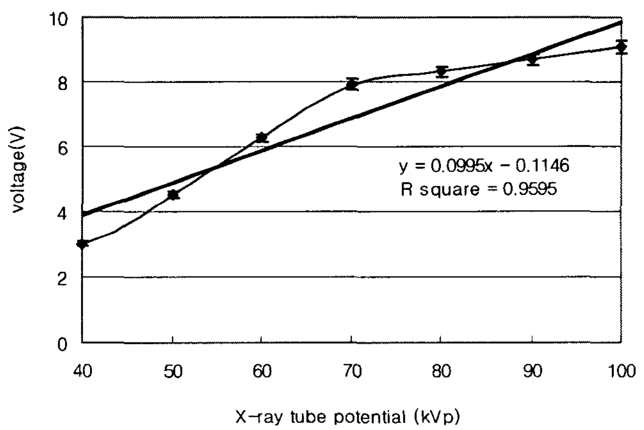

Fig. 6. The relation between the response of CdS sensor and X-ray tube potentials.

2. Response of CdS sensor with respect to the X-ray tube current (mA) variations

Fig. 7, 8 present the responses of CdS sensor to various conditions of X-ray tube current (mA). Table 2 shows the calculted standard deviation that has small value. It means that the responses of CdS sensor to various conditions of X-ray tube current tend to be good characteristics of reproducibility and stability.

Fig. 7 shows the voltage response of CdS sensor to the variations of X-ray tube current. The voltage responses of CdS sensor increases according to the increasing X-ray tube-current from 40 mA to 320 mA. Fig. 8 shows the linear characteristics (y=0.0439x+1.1891, R^2=0.9021). Like the responses of CdS to X-ray tube potential, This value is not absolute value.

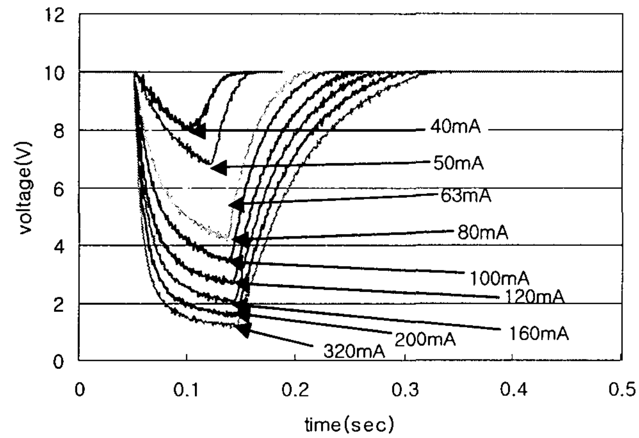

Fig. 7. The response of CdS sensor according to the various X-ray tube currents from 40 mA to 320 mA.

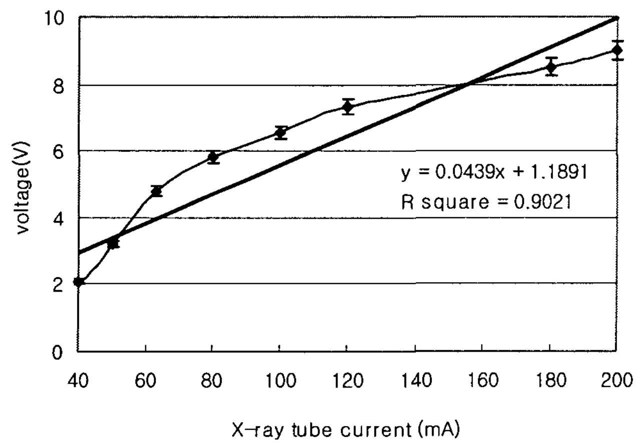

Fig. 8. The relation between the response of CdS sensor and X-ray tube currents.

Fig. 9 shows the voltage response of CdS sensor to the variations of X-ray exposure time. The voltage response of CdS sensor increased as the X-ray exposure time increased. We also calculated the standard deviation (Table 3), and investigated the properties of stability and reappearance.

Fig. 9 shows the voltage response of CdS sensor to the variations of X-ray exposure time. The voltage responses of CdS sensor increases according to the increasing X-ray exposure time from 0.04 to 0.3 s. Fig. 10 shows the linear characteristics (y=8.2853x+5.5878, R^2=0.7287). This value is the difference of voltage area than the change of peak voltage. So, the change of peak voltage is little

Table 2. Standard deviation of the CdS voltage response for the tube currents of 40, 50, 63, 80, 100, 120, 160, 200, 320 mA

mA	40	50	63	80	100	120	160	200	320
Std. Deviation	0.02	0.02	0.03	0.08	0.08	0.06	0.05	0.02	0.02

Table 3. Standard deviation of the CdS voltage response for X-ray exposure time

Second	0.04	0.08	0.12	0.20	0.25	0.3
Std. Deviation	0.02	0.02	0.03	0.07	0.05	0.16

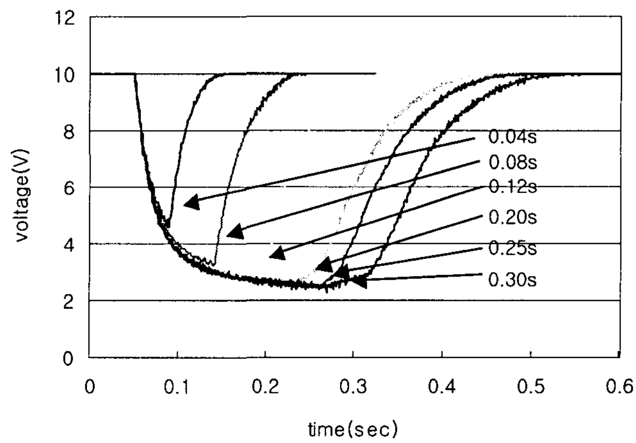

Fig. 9. The response of CdS sensor according to X-ray exposure time variation.

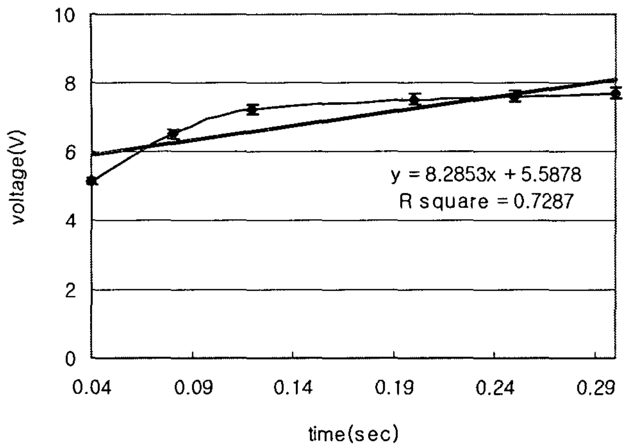

Fig. 10. The relation between the response of CdS sensor and X-ray exposure time variation.

CONCLUSIONS

First, the voltage response of CdS sensor to the variations of X-ray tube potential was a linear characteristics and had a small stadnard deviation(y=0.0995x-0.1146, R^2=0.9595). The voltage response of CdS sensor to the variations of X-ray tube current had a linear characteristics (y=0.0439x+1.1891, R^2=0.9021). The voltage response of CdS sensor is changed little the variations of X-ray exposure time. The voltage response of CdS sensor to the variations of X-ray exposure time is the difference of voltage area rather than the change of peak voltage (y=8.2853x+5.5878, R^2=0.7287). In conclusion, CdS not only responds to X-ray linearly but also is feasible as X-ray sensor of multi-functional dosimeter. Our next research will be the detection properties of CdS at high X-ray current conditions according to studying of CdS's thickness and properties.

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다기능 선량계로서의 Cadmium sulfide의 X-선에 대한 특성 평가

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다기능 X-선 선량계로서의 cadmium sulfide의 X-선에 대한 특성을 평가하기 위해 cadmium sulfide 기반의 X-선 선량계를 진공 증착법을 사용하여 제작하였으며 X-선 노출에 따른 cadmium sulfide의 반응을 측정하였다. Cadmium sulfide의 X-선 관전압, 관전류, 조사시간에 따른 전압의 변화를 측정하여 이를 분석하였다. X-선의 관전압에 따른 cadmium sulfide의 반응을 회귀분석을 통해 통계처리 한 결과 y= 0.0995x-0.1146 (R^2=0.9595, σ=0.08, standard error=2%) 이고 X-선 관전류에 따른 cadmium sulfide의 출력신호를 분석한 결과 y=0.0439x+1.1891 (R^2=0.9021, σ=0.04, standard error=1.8%)였다. 또한 X-선 조사시간에 따른 cadmium sulfide의 반응을 같은 통계 방법으로 통계처리한 결과 y=8.2853x+5.5878 (R^2=0.7287, σ=0.06, standard error=1.9%) 였다. 결론적으로 cadmium sulfide의 X-선에 대한 반응은 X-선의 에너지가 증가됨에 따라 선형적으로 반응함을 알 수 있었으며 제작된 cadmium sulfide의 X-선의 다기능 선량계로서의 그 사용 가능성을 제시하고자 한다.

중심단어 : X-선, Cadmium Sulfide, 선량계