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Measurement of the properties of a flat-panel gas X-ray detector

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ABSTRACT

Recently, large-area image detectors were investigated for X-ray imaging in medical diagnostic and other applications. In this paper, a new flat-panel gas detector for diagnostic X-ray imaging is proposed, and its characteristics are investigated. Research on flat-panel gas detectors is scarce, because of the difficulties of injecting gas against atmospheric pressure. So almost all gas detectors are designed as a chamber. We made a flat-panel sample by display technique (e.g. plasma display panel, field emission display, etc.). Transparent electrodes, dielectric layer, and MgO protection layer were formed in the front glass. Additionally, X-ray phosphor layer and address electrodes were formed in the rear glass. Dark current, X-ray sensitivity, and linearity as a function of electric field were measured to investigate the electrical properties. From the results, the stabilized dark current density and significant X-ray sensitivity were obtained. A good linearity as a function of exposure dose could be realized in a wide diagnostic energy range. These results mean that the passive matrix-addressed flat-panel gas detector can be used for digital X-ray imaging.

1. Introduction

Films and screens are used to acquire conventional radiographic images by capturing the pattern of X-rays transmitted through a patient. Recently, however, as the problems of films and screen-based medical imaging systems have become recognized, digital radiography (DR) technology has been developed to make up for the problems [1]. There are several DR systems such as computed radiography (CR), flat-panel detectors, and CCD- or CMOS-based systems. It is expected that DR-based flat panels will be useful as they provide images of good quality with low dose [2,3]. In this paper, a new flat-panel gas detector for diagnostic X-ray imaging is proposed, and its characteristics are investigated. We also verified the possibilities of using the flat-panel gas detector as an X-ray detector by investigating dark current, sensitivity, and linearity.

2. Experimental method

2.1. Fabrication of the gas X-ray detector

For the experiment, the detector was manufactured with transparent electrodes, dielectric layer, and MgO protection layer in the front glass. X-ray phosphor layer and address electrodes were formed in the rear glass. Then the mixed gas (Xe+Ne) was injected between front and rear glass. Silver electrodes were formed by screen-print equipment. Then the electrodes were annealed at temperatures below 500 °C. After that the dielectric layer was deposited on the electrode layer. It was annealed at 550 °C. The CsI phosphor layer was deposited on the dielectric layer. Then we injected the mixed gas, 90% Xe+10% Ne, between the front glass and rear glass. The manufacture processing is shown in Fig. 1 and a picture of the manufactured sample is shown in Fig. 2.

2.2. Electrical properties

Fig. 3 shows a block diagram of the setup to measure dark current linearity and X-ray sensitivity as a function of electric field, and dependence of linearity properties on X-ray exposure dose.

The experimental setup consisted of a power supply (EG&G 558H, USA) for voltage application and an electrometer (Keithley 6517A, USA). The X-ray generator unit was a Shimadzu TR-500-125 (Japan), and the radiation dose was monitored using Ion Chamber 2060 (Radical Cooperation, USA).

For evaluation of the electrical properties of the manufactured detector, we performed *I–V* measurements. We obtained a low dark current and significant sensitivity to X-rays. After that we tested the linearity of the detector dependence on X-ray dose.

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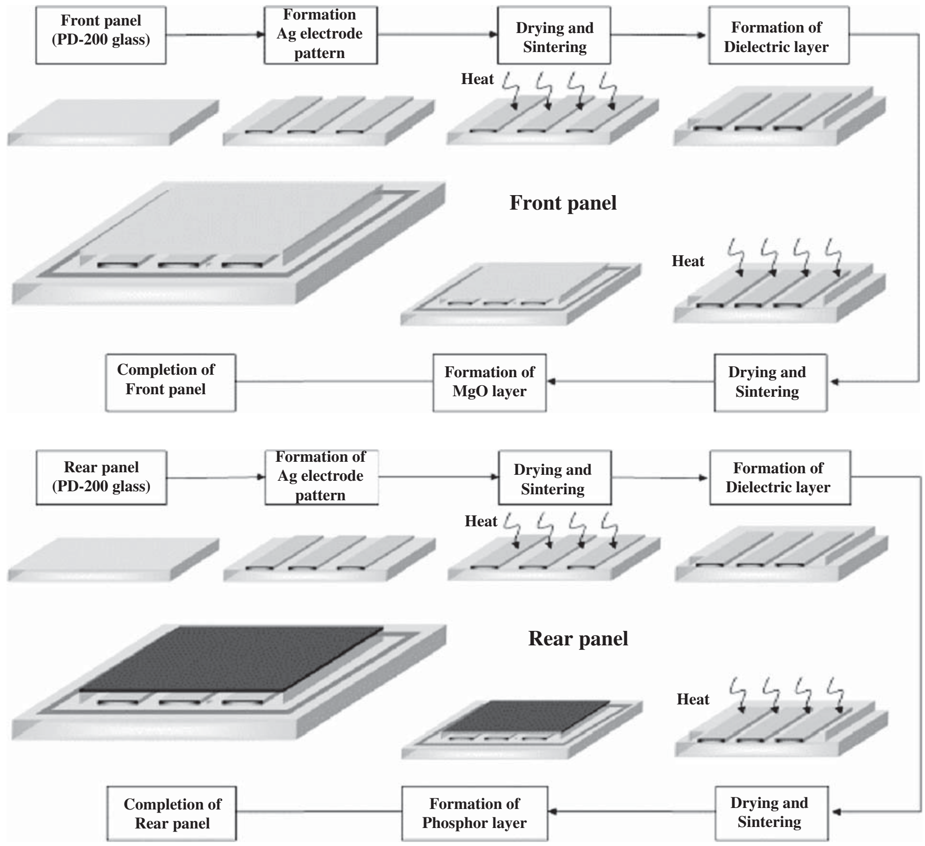

Fig. 1. Manufacturing processing of a front and a rear panel.

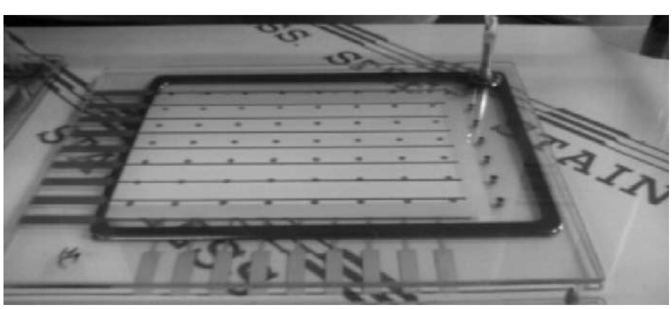

Fig. 2. Manufactured sample with 90% Xe+10% Ne.

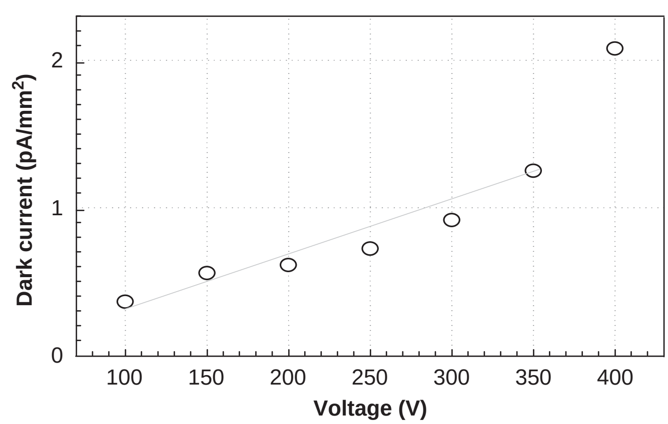

Fig. 4. Dark current as a function of applied voltage.

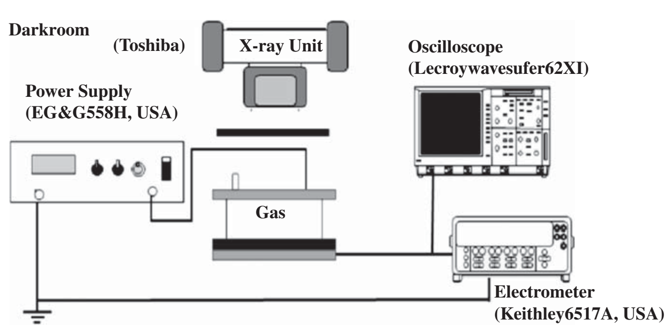

Fig. 3. Block diagram for the measurements of dark current and X-ray sensitivity.

The measurement of linearity was carried out at the same voltage by a variation of X-ray dose.

3. Results

3.1. The dark current and sensitivity

The dark current and sensitivity of the detector dependence on applied voltage are shown in Figs. 4 and 5. We obtained a dark current of $0.09\,nA/cm^2$ and a sensitivity of $0.15\,nC/mR\,cm^2$ at

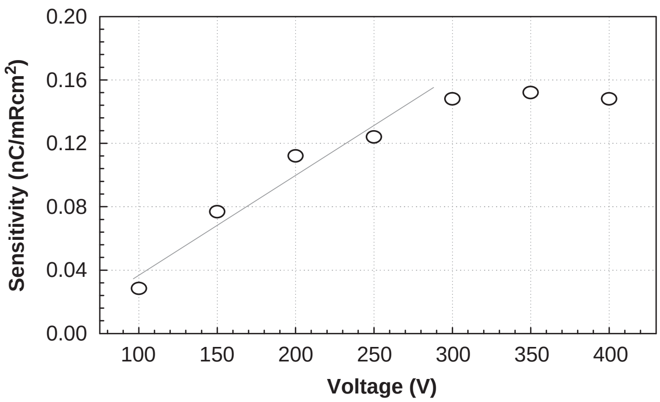

Fig. 5. X-ray sensitivity as a function of applied voltage.

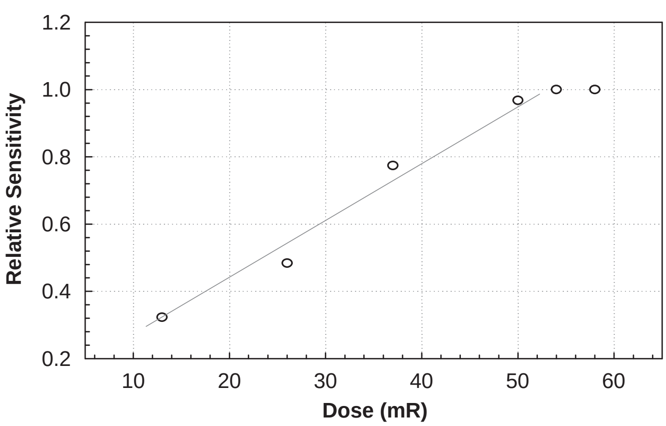

Fig. 6. Sensitivity in dependence on dose as a test of linearity.

300 V. The result of the very low dark current is impressive. We obtained a signal-to-noise ratio (SNR) of 52 at that voltage.

3.2. Linearity property

Linearity is very important for a radiation detector because this defines its dynamic range. We measured the linearity by changing the X-ray dose (current in the tube and kVp) at fixed voltage. Fig. 6 shows results of this measurement. We defined 1.0 as the value of saturation sensitivity. It shows a linear increment of sensitivity with X-ray dose.

3.3. Variation of the collected charge in the flat-panel gas detector

We carried out measurements to investigate the influence of cross-talk. The flat-panel gas detector sample is composed of 8 vertical stripes and 9 horizontal stripes as shown in Fig. 2. There are 72 pixels in this panel. We measured the sensitivity in all pixels. As shown in Fig. 7, the spread in sensitivity is $\pm 5\%$. In this study, pixel pitch is large with about 1 cm. In the future we will make a sample with reduced pixel pitch and try to reduce the amount of cross-talk.

4. Conclusions

In this contribution we confirmed a possible use of flat-panel gas detector as X-ray detector. The dark current and sensitivity permit sufficient possibility for using the radiation detector. Also the linearity property is a promising result. Through more research, we are aiming to reduce the amount of cross-talk.

We plan to develop a panel with better performance by changing the filling gas to one with higher atomic number for better response to X-rays, changing the material of the phosphor

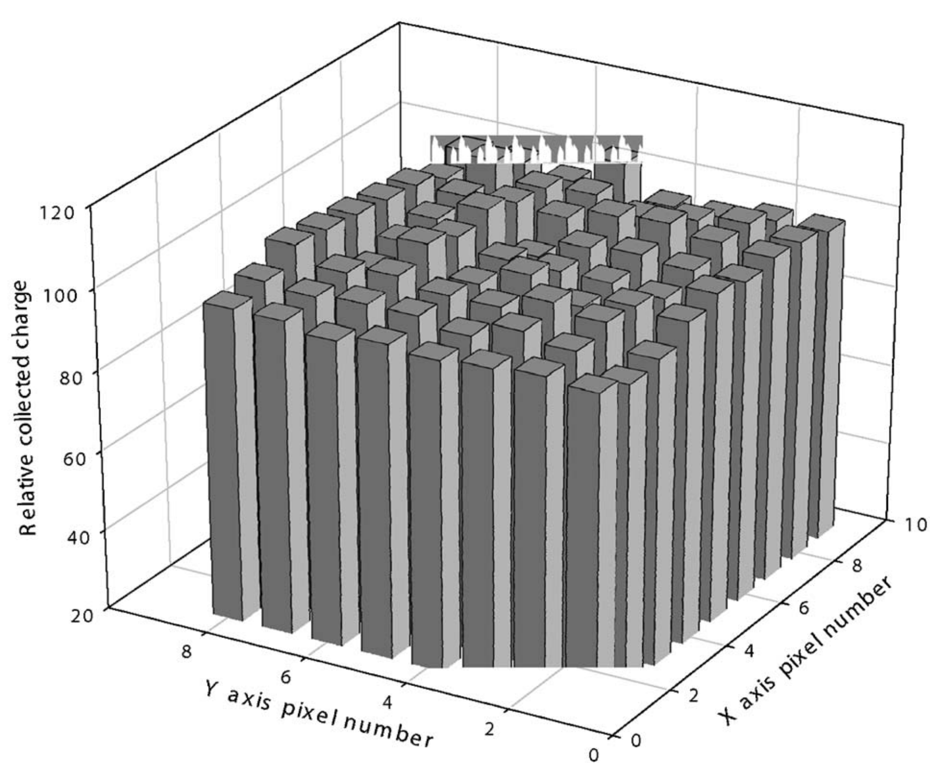

Fig. 7. Relative collected charge in each pixel of the flat-panel gas detector.

layer, adding a photoconductive layer to obtain more signals, and changing the structure of the electrodes to reduce cross-talk.

Acknowledgments

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