17-in. × 17-in. flexible flat panel X-ray detectors with high Image quality and light weight

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ABSTRACT

We developed 17-in. × 17-in. flexible flat-panel X-ray detectors combining an irradiation side sampling system with flexible photodiode and thin-film transistor technology. The proposed flat-panel detectors had 10% higher detective quantum efficiencies and 35% lesser weights than conventional rigid detectors.

1 Introduction

Cassette-type digital radiography (DR) detectors comprising indirect conversion flat-panel detectors (FPDs) are widely used in general radiography because of their advantages, such as high image quality, large detection area, high-speed readout, and portability (Fig. 1).

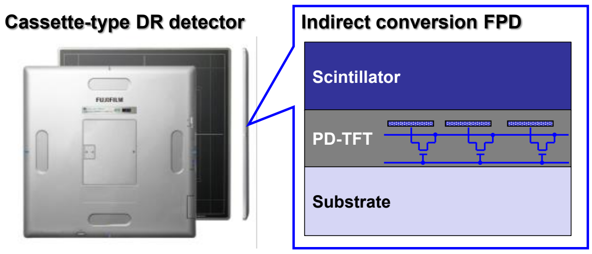

Fig. 1 Example of a cassette-type DR detector.

Indirect conversion FPDs are classified into two types as penetration side sampling (PSS) and irradiation side sampling (ISS) systems depending on the positional relationships between the X-ray irradiation direction, scintillator, and flexible photodiode with thin-film transistor (PD-TFT) substrate, as shown in Fig. 2. Sato et al. reported that the ISS system enabled effective detection of the light emitted from a scintillator near the photodiode, thereby resulting in higher sensitivity and resolution than common PSS systems [1]. However, the conventional ISS systems use rigid glass for the PD-TFT substrates, where X-ray absorption and scattering by the glass substrate remain issues to be addressed.

Recently, cassette-type DR detectors have been increasingly applied in not only conventional hospital and clinical use but also home medical care. Therefore, further image quality improvement, X-ray dose reduction, and device weight reduction are desired for these detectors. To achieve these goals, we developed novel FPDs with high image quality and light weight by combining the ISS system and flexible PD-TFT technologies [2]. This paper presents the structures, fabrication processes, and results of the image quality evaluations of the ISS system flexible FPDs and compares them with those of the conventional ISS system rigid FPDs.

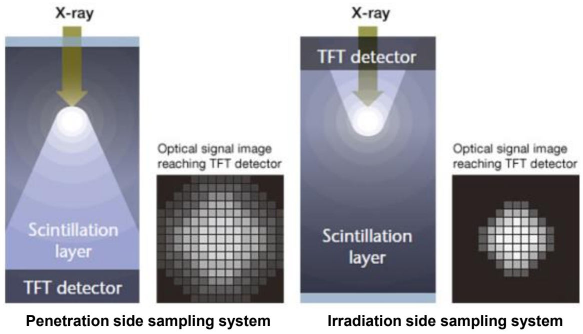

Fig. 2 Indirect FPD architectures (PSS vs. ISS).

2 Experiments

2.1 Detector Structure

Fig. 3 shows the cross-sectional image and photograph of the ISS system flexible FPD. The PD-TFT substrate of the FPD was a 40 μm polyimide (PI) film, through which X-rays were irradiated on the substrate surface.

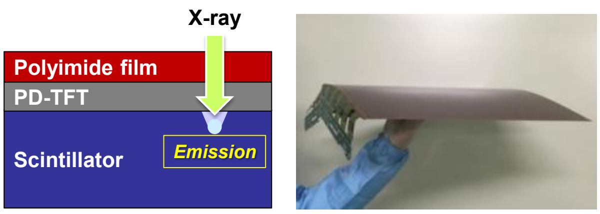

Fig. 3 Schematic cross section (left) and photo (right) of the novel ISS system flexible FPD.

We developed two types of FPDs with Gd_2O_2S:Tb (GOS) and CsI as the scintillators, with a pixel size of 150 × 150 μm^2, 2848 × 2840 number of pixels, and an active area of 17-in. × 17-in. for each detector. We also prepared conventional ISS system FPDs for use as reference, where the PD-TFT substrate was 0.5 mm rigid glass. The weights of the flexible FPDs were 35% less than those of the conventional FPDs for both GOS and CsI scintillators.

2.2 Fabrication Process

The flexible FPDs were fabricated using flexible device transportation technology, including the bonding and debonding processes, as shown in Fig. 4. We adopted and optimized the transportation system developed by the display device industry for our novel FPDs.

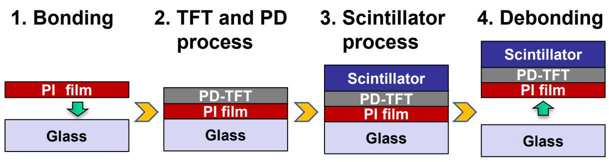

Fig. 4 Schematic showing fabrication process of the ISS system flexible FPD.

2.3 Evaluation Method

We evaluated the sensitivity, modulation transfer function (MTF), and detective quantum efficiency (DQE) of the two FPDs. The sensitivity was determined using the quantity of electric charge generated on the pixels during X-ray irradiation and the X-ray irradiation dose. The MTF and DQE were measured according to the IEC 62220-1 standard. The data were obtained for four standard radiation qualities, namely RQA3, RQA5, RQA7, and RQA9, as defined by the IEC 61267 standard. The MTF was expressed as a relative value, when the conventional FPD MTF of 1 cycle/mm in RQA5 was assumed to be 100 for both the GOS and CsI scintillators. To investigate the image qualities of the entire active areas of the flexible FPDs, we obtained chest phantom images using FUJIFILM's cassette-type DR detector system.

3 Results and Discussion

3.1 Sensitivity

Fig. 5 shows the rate of increase of the sensitivity of the flexible FPDs compared with those of conventional FPDs for each radiation quality. For both the GOS and CsI scintillators, the sensitivities of the flexible FPDs were higher than those of the conventional FPDs for all radiation qualities. The increase in sensitivity was particularly large for the softer radiation qualities, namely RQA3 and RQA5. It is considered that the lower X-ray absorption of the 40 μm PI film relative to that of the 0.5 mm glass substrate contributed toward the increase in sensitivity of the flexible FPDs.

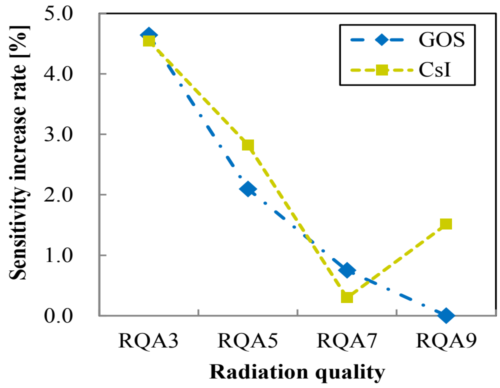

Fig. 5 Rate of increase of sensitivity of the flexible FPDs compared with those of conventional FPDs for each radiation quality.

3.2 MTF

A comparison of the relative MTF curves of the flexible and conventional FPDs for RQA5 is shown in Fig. 6. The flexible FPDs showed slightly higher MTFs than the conventional FPDs for both scintillators over the entire measured spatial frequency range. The lower X-ray scattering of the 40 μm PI film compared with that of the 0.5 mm glass substrate is considered to contribute toward the higher MTF of the flexible FPD.

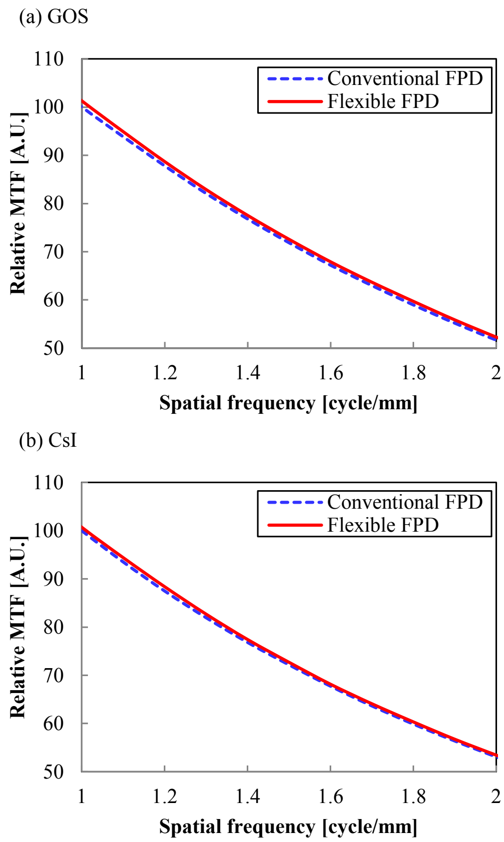

Fig. 6 Relative MTF curves of the ISS system flexible and conventional FPDs for (a) GOS and (b) CsI scintillators for the RQA5 quality.

3.3 DQE

The DQE curves for the RQA5 quality for both the flexible and conventional FPDs are shown in Fig. 7. The flexible FPDs ore observed to have higher DQEs than the conventional FPDs for both scintillators over the entire measured spatial frequency range. The higher DQEs of both types of flexible FPDs are attributed to the increases in their sensitivities and MTFs.

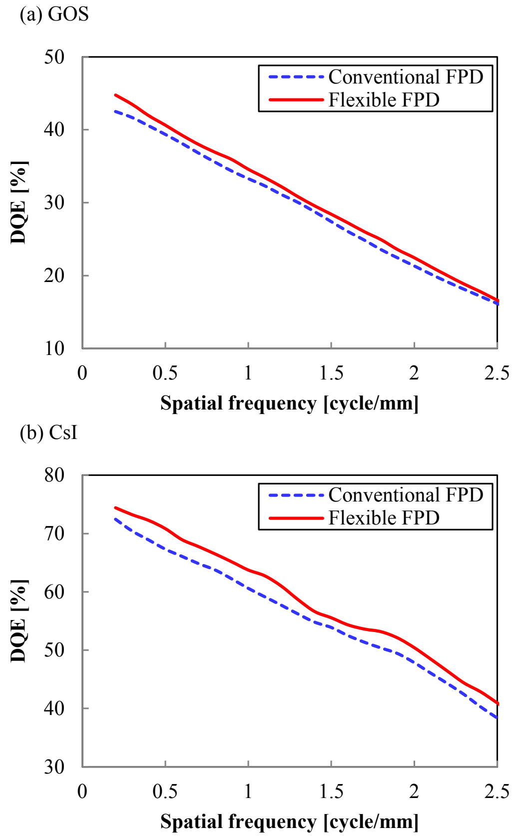

Fig. 7 DQE curves of the ISS system flexible and conventional FPDs for (a) GOS and (b) CsI scintillators for the RQA5 quality.

3.4 Image Quality of Entire Active Area

Fig. 8 shows an example chest phantom image obtained using the ISS system flexible FPD with the CsI scintillator. The image quality is observed to be good, and no flexible-FPD-specific artifacts are visible over the entire 17 × 17 inch active area.

Fig. 8 Example of chest phantom image obtained using the ISS system flexible FPD with the CsI scintillator.

4 Practical Application

We applied the proposed device technology to actual cassette-type DR detector products. FUJIFILM's FDR D-evo III series (DR CALNEO Flow series in Japan), which is based on the ISS system flexible FPD technology, has been shown to achieve higher sensitivity and dramatically reduced weight for improved usability compared with the conventional systems with FPDs made of glass substrates (Fig. 9).

Fig. 9 Practical application examples of the ISS system flexible FPD technology (DR CALNEO Flow series)

5 Conclusion

We developed novel ISS system flexible FPDs with GOS and CsI scintillators using 40 µm PI film substrates. These FPDs can realize higher sensitivities, MTFs, and DQEs than the conventional FPDs for both scintillators. Additionally, we achieved approximately 35% weight reduction with the flexible FPDs compared with the conventional FPDs having glass substrates. Therefore, the proposed FPDs can contribute to image quality improvement, X-ray dose reduction, and weight reduction with cassette-type DR detectors.

References

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