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Feasibility Study of an Active Sandwich Detector for duel-energy imaging

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1. Introduction

Dual-energy (DE) imaging can remove overlapping background structures that obscure the detection and characterization of target object in radiographs. Although the theoretical framework describing DE imaging had been initialized in the late of 1970s [1], its renewed interest has been in the spotlight since large-area flat-panel detectors capable of real-time imaging with high detective quantum efficiency had been commercially available. DE x-ray imaging based on the fast kVp-switching technique (also known as "double-shot or double-exposure" DE imaging), which acquires low- and high-energy projections in successive exposures, is therefore now available in clinic [2].

Figure 1(a), (b) and (c) show preparations of "single-shot or single-exposure" DE imaging detector, which acquires low- and high-energy projections simultaneously from two detectors arranged in upper and lower layers. Since two detectors are doubly-layered, we named it "the sandwich detector". While sandwich-detector configurations based on "passive" film-screen combinations or storage phosphors were often reported [3], there has not been sufficient attention paid to the use of "active" solid-state detectors. In this study, we investigate a feasibility of sandwich detector based on flat-panel detectors for dual-energy x-ray imaging, particularly for industry application such as a foreign substance detection in noodles [Fig. 2(d) and (e)].

2. Methods and Materials

We employed a flat-panel detector consisting of a matrix-addressed photodiode array (RadEye^{TM}1, Rad-icon Imaging, DALSA Corp., USA) fabricated by a complementary metal-oxide-semiconductor (CMOS) process coupled to a terbium-doped gadolinium oxysulfide (Gd_2O_2S:Tb) phosphor screen (Min-R^{TM} 2000, Carestream Health, Inc., USA) as an x-ray-to-light converter [4]. The CMOS detector featured a small 0.048-mm-sized pixel arranged in 512×1024 format. The sandwich detector can be configured by stacking two CMOS detectors of which each phosphor screen faces each other. For the better spectral decomposition between response functions obtained from upper and lower detectors for a single exposure, filter material can be inserted between two CMOS detectors so that can obtain an energy separation for DE imaging as shown in Fig. 2.

To decompose a foreign substance image from two different energy projections, we applied the weighted log-subtraction arithmetic [2]. The optimal weighting factor to cancel overlapping structures have also investigated in this study.

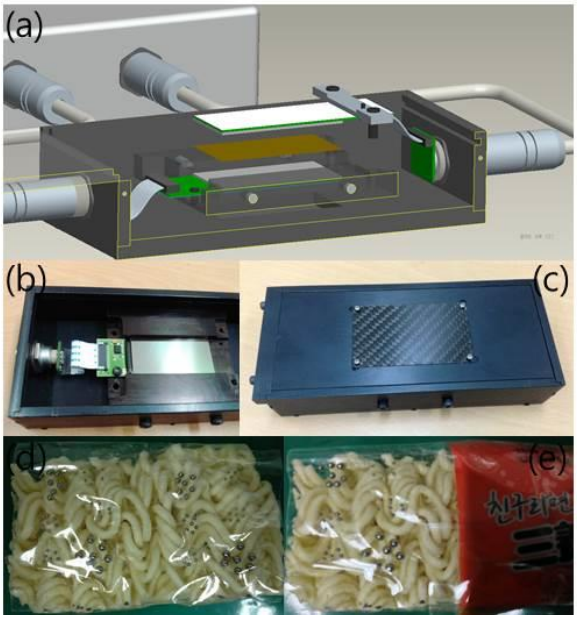

Fig. 1. CAD drawing and pictures of the sandwich detector and noodle with foreign substance phantom.

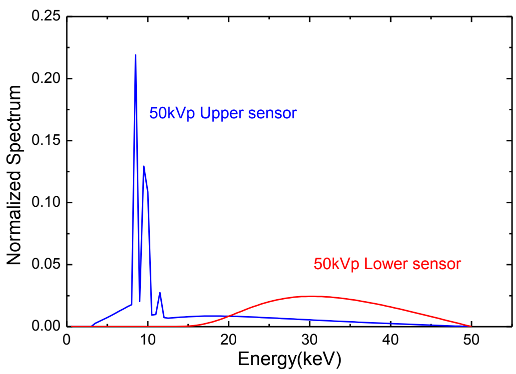

Fig. 2. Normalized x-ray spectrum expected in the lower and upper sensor with 50kVp incident spectrum.

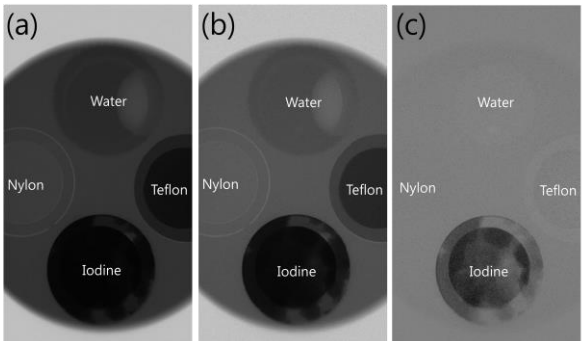

Fig. 3. (a) and (b) show the low- and high-energy projections obtained from the upper and lower detectors, respectively. (c) shows the iodine-only image obtain from the weighted log-subtraction between (a) and (b).

3. Preliminary results

Figure 3 demonstrates the single-shot DE x-ray imaging with a sandwich detector. It should be noted that, at that time, the high-energy projection from the lower-layer CMOS detector was obtained by putting the aluminum layer, whose thickness was equivalent to the CMOS detector so as to yield the same attenuation, onto the lower CMOS detector. Figure 3(a) and (b) show the low- and high-energy projections, respectively. The iodine-only image from the weighted log-subtraction between two projections is shown in Fig. 3(c) and the result is promising.

4. Summary

We have successfully demonstrated the dual-energy x-ray imaging with the active sandwich-detector configuration. The imaging performance of the sandwich detector will be reported by using a quantitative phantom for industry application.

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