SCINTILLATION SCREEN PREPARATION FOR USE IN DIGITAL MEDICAL IMAGING SYSTEMS

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Abstract. *Radiation detectors, employed in X-ray medical imaging, consist of a scintillating (fluorescent) screen emitting visible light coupled to optical sensors. Screens are fabricated by specially developed scintillators (phosphors). Up to now scintillation screens were prepared by sedimentation on fused silica substrate (spectrosil B) in a form of transparent disk 30mm in diameter and 3mm in thickness. A new sedimentation method is proposed by deposition of scintillation powders on rectangular Borosilicate glass substrate 22x22 mm^2 with thicknesses of 0.13-0.17 mm (Waldemar Knittel-GmbH). The optical properties of the substrate were examined in terms of light absorption and transmission in the range between 200-800nm (visible range) and found adequate for use with the common scintillation powders (transmissivity 95%). New screens of various coating thicknesses were examined under medical X-ray irradiation, placed in direct contact with a CMOS (RadEye) optical detector. X-ray images of a test object demonstrate the fine quality and spatial resolution of the above screens. Due to the rectangular shape of the substrate images taken from the prepared screens are indicative for their potential use in the X-ray digital medical systems.*

1 INTRODUCTION

The combination of light sensitive digital detectors with efficient scintillators can be beneficial not only in the reduction of the overall detector production cost but also to the reduction of the total dose to the patient[1]. Radiation detectors, employed in X-ray medical imaging, consist of a scintillating (fluorescent) screen emitting visible light coupled to optical sensors. Screens are fabricated by specially developed scintillators (phosphors)[2]. Sedimentation has been a widely accepted technique for preparation of radiographic phosphor screens with good homogeneity and spatial resolution[3,4]. Screens of any area with the desired coating thickness can be obtained, with a packing density of the order of 50% which is common in commercial phosphor screens[4]. Other techniques such as sintering have been also employed providing ceramic scintillating screens with high packing density and good homogeneity. It was previously found that such screens can show improved resolution[5, 6]. However the method is more complex and not well established yet.

Up to now scintillation screens prepared by our group were on fused silica substrate (spectrosil B) in a form of transparent disk 30 mm in diameter and 2.5 mm in thickness [3]. Such disks are difficult to be employed in digital imaging detectors since the latter are using in most cases rectangular light sensitive areas[7, 8].

A new sedimentation method is proposed by deposition of scintillation powders on rectangular Borosilicate glass substrate 22x22 mm^2 with thicknesses ranging from 0.13 to 0.17mm (Waldemar Knittel-GmbH). Two screens with thicknesses (coating density) 32.1 mg/cm^2 for mammography and 64.9 mg/cm^2 for radiography were prepared and tested under medical X-ray imaging conditions. Results were comparable and even better than those obtained with the cylindrical screens due to the thinner substrate.

2 MATERIALS AND METHODS

Sedimentation is the simplest and most widely accepted method for preparation of phosphor screens for industrial and research use. It is composed by the preparation of a suspension of the phosphor to be used and the slow sedimentation of it onto a substrate. Powder Gd_2O_2S:Eu was purchased from

Phosphor Technology Ltd, England (code: UKL63/N-R1), with mean grain size of approximately 8 μm and a density of 7.3 g/cm^3. Particle size and morphology parameters of the Gd_2O_2S:Eu powder phosphor were verified via scanning electron microscope (SEM) micrographs. For the preparation of the suspension, deionized water was used in which the above phosphor is practically insoluble. Sodium silicate water solution (Na_2Si0_3) or so called "waterglass" was used as binding material, which creates conditions of satisfactory adhesion of phosphorus layer (refractive index of solution = 1.353, refractive index Na_2Si0_3 = 1.53) [9]. The sedimentation achieved by using a mixture consisting of 1000 ml of de-ionized water, 20 ml of Na_2SiO_3, and the appropriate amount of phosphor powder in a glass tube of 110 cm height (Figure 1). The substrate was placed at the bottom of the tube[10, 11] and secured using a silicone optical compound as an adhesive media (Visilox V-788). This compound can be easily removed afterwards by using an alcohol based solution without leaving any light absorbing stains. The sedimentation is followed by the removal of fluid, slowly drying the screen without any movement for 24 hours at room temperature. Then was placed in an oven for 2 hours at a temperature of 150 °C, and then was slowly cooled to the temperature of the environment. Two relatively thin screens were prepared with thickness (coating density) 32.1 mg/cm^2 and 64.9 mg/cm^2 respectively on Borosilicate glass substrate 22x22 mm^2 (Waldemar Knittel-GmbH).

Figure 1. The sedimentation apparatus used for the production of Gd_2O_2S:Eu phosphor screens.

The screen coating density (mg/cm^2) can be found according to next equation:

$$E = \frac{m_1 - m_2}{S} \tag{1}$$

Where E is the screen coating density (mg/cm^2), m_1, m_2 are the masses of the substrate after the sedimentation with the phosphor material on it and before sedimentation respectively (in mg). S is the substrate surface (in cm^2).

The two Gd_2O_2S:Eu phosphor screens, were coupled to an optical readout device including a CMOS Remote RadEye HR photodiode pixel array. The CMOS photodiode array consists of 1200x1600 pixels with 22.5 μm pixel spacing.

The Gd_2O_2S:Eu screens were directly overlaid onto the active area of the CMOS photodiode array, consisting of an N-well diffusion on p-type epitaxial Silicon, and held by using a thin Polyurethane foam layer for compression between the screen and a 1-mm-thick Graphite cover. Experiments, on the

CMOS optical sensor, were carried out in both X-ray mammography and radiography energy ranges.

3 RESULTS AND DISCUSSION

The optical properties of the substrate were examined in terms of light absorption and transmission in the range between 200-800 nm (visible and near IR range). Figure 2 shows the light transmittance of the substrate, using a Perkin-Elmer UV/Visible lambda 15 Spectrophotometer. In the visible range, the light transmittance is close to 90%, a value which is close to the manufacturer's data sheet for the substrate used. Since most scintillation powders under irradiation emit light in the visible range, the above measurements are adequate in characterizing the substrate.

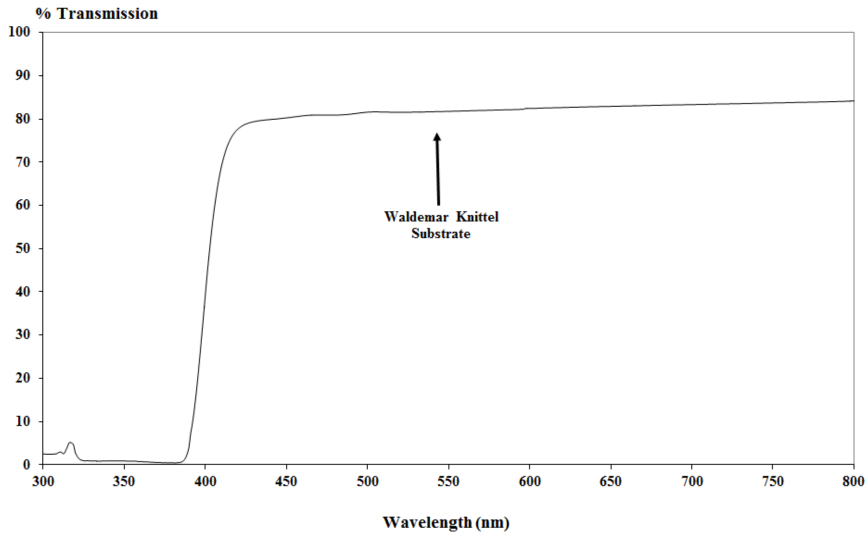

Figure 2. The normalized optical transmission of the rectangular Borosilicate glass substrate 22x22 mm^2 with thickness of 0.13-0.17 mm (Waldemar Knittel-GmbH), using a Perkin-Elmer UV/Visible lambda 15 Spectrophotometer

Figure 3a shows the 32.1 mg/cm^2 , Gd_2O_2S:Eu prepared screen under UV irradiation. Gd_2O_2S:Eu emits red light under ionizing radiation exposure. The light emission of the screen was almost uniform. As shown in Figure 3a there are some areas of low intensity due to non-uniform phosphor powder deposition. A possible cause for this can be attributed to the drainage procedure following sedimentation. If the drainage is not very slow, turbulence in the periphery of the substrate can cause non-uniform deposition of the phosphor. Taking into account the above considerations, a second Gd_2O_2S:Eu screen with coating density 64.9 mg/cm^2, was prepared using a very slow drainage procedure. The non-uniformities on the phosphor deposition at the periphery of the substrate were almost eliminated. Figures 3b and 3c show the image of a car alarm remote control, taken using the two Gd_2O_2S:Eu screens, directly overlaid onto the active area of the CMOS Remote RadEye HR photodiode pixel array.
Figure 3b shows an image taken under 25 kVp, 63mAs X-rays (mammography conditions) and Figure 3c shows an image taken under 80kVp, 63mAs X-rays (radiography conditions).

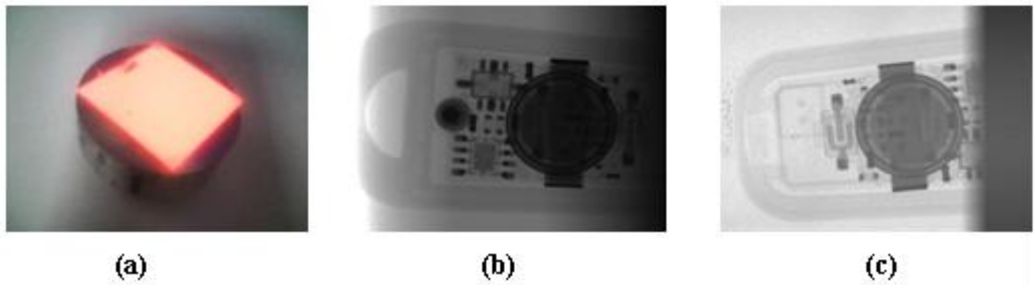

Figure 3. Acquired images of the Gd_2O_2S:Eu phosphor deposited on a thin Borosilicate glass substrate (Waldemar Knittel-GmbH), a) the 32.1 mg/cm^2 screen under UV irradiation, b) an X-ray image (25kVp, 63mAs) of a car alarm remote control using the 32.1 mg/cm^2 screen directly overlaid onto the active area of the CMOS optical detector and c) an X-ray image (80kVp, 63mAs) of the above remote control using the 64.9 mg/cm^2 screen directly overlaid onto the active area of the CMOS optical detector.

As can be observed from figures 3b and 3c the resolution of the acquired images is relatively good, and the prepared Gd_2O_2S:Eu screens can be easily adopted to digital detectors, used for medical imaging.

4 CONCLUSIONS

This method gives adequate screen uniformity and good resolution, which is characterized by the simplicity of the technique, the low loss of the phosphor material during the screen preparation and the full preservation of the properties of phosphor, since it does alter the composition and the grain size of the material.

The amount of the phosphor that stays on the substrate is 30.5% of the initial phosphor powder, compared to 25% when using the previous method (thick cylindrical substrates). Due to the thinner substrate, more light can be collected on the detector's light sensitive area which in turn, may lead to the reduction of the patient dose

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