

Resolving power of scintillation panels based on zinc selenide

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Received November 30, 2011

This work presents some characteristics of experimental samples of flexible scintillation panels made on the basis of fine-powders of zinc selenide scintillator. The purpose of the work was to determine the resolving power of dispersed scintillation panels based on ZnSe(Te) and to clarify the field of their application in X-ray technique. In the course of studying the dependences of the resolving power of scintillation panels based on ZnSe(Te) on the powder particles size and thickness of the panels were discovered. The data on the dependences of the light output on the panel thickness and particle size of the scintillator in the samples in the thickness range of 0.1–1 mm are presented. X-ray images of different test objects obtained using scintillation panels based on zinc selenide are shown. Three ranges of the particles dispersion were investigated: the first — 25–40 μm, the second — 40–120 μm, and the third — 120–200 μm. It was revealed that the resolving power was 5, 3 and 2.5 lp/mm for the each range of dispersion.

Представлены характеристики экспериментальных образцов гибких сцинтилляционных панелей, изготовленных на основе мелкодисперсных порошков селенида цинка. Изучена зависимость пространственного разрешения сцинтилляционных панелей на основе ZnSe(Te) от размера частиц порошка сцинтиллятора и толщины панелей. Представлены данные о зависимости светового выхода панелей от толщины и размера частиц сцинтиллятора в образцах в диапазоне толщин 0,1–1 мм. Показаны рентгенографические снимки различных тест объектов, полученные с помощью сцинтилляционных панелей на основе селенида цинка. Исследовано три диапазона дисперсности частиц: первый — 25–40 мкм, второй — 40–120 мкм, третий — 120–200 мкм. Установлено, что простанственное разрешение составляет 5, 3, 2.5 пар линий/мм для соответствующих диапазонов. Определено пространственное разрешение дисперсных сцинтилляционных панелей на основе ZnSe(Te) для выяснения их области применения.

1. Introduction

ZnSe(Te) scintillator relates to the semiconductor materials class of A_2B_6 group. It is widely used in scintillator-silicon photodiode systems for X-ray detectors of modern multichannel low energy devices for visualization of hidden image (systems of non-destructive control, medical tomography, radiography) [1]. Crystals of zinc selenide possess a high luminescent efficiency (60 thousands photons/MeV) and short afterglow duration, which allows registration of the shadow image of biological objects in real time. Also the emission color of this phosphor is orange-red, which makes it perfectly suited to detection by silicon semiconductor devices [2].

As scintillation material ZnSe(Te) can be used in crystal and powder form [3]. On the basis of powder zinc selenide the flexible scintillation panels with high light yield and homogeneity of the luminescence were developed [4]. These flexible scintillation panels made for application in X-ray studies of biological objects in medical tomography, industrial defectoscopy and other low energy devices of visualization of hidden image, for example, the systems of X-ray scanning of passenger's baggage in the airports or vehicles scanning in the customs stations. Scintillation panels are designed for use with multi-channel silicon photodiodes, CCDs and other photodetection devices of linear and complex shape.

For successful application of the scintillation panel in X-ray equipments it has to possess the number of necessary features such as satisfactory contrast sensitivity and resolving power in a wide dynamic range. Depending on the type of X-ray system the resolving power can vary by up to 20 lp/mm for the traditional film radiography, about 10 lp/mm for combined systems of film and intensifying screen and from 0.7 to 4–5 lp/mm for digital radiography [5, 6].

The purpose of this work was to find out the resolving power of scintillation panels based on ZnSe(Te) and their optimal parameters for keeping a compromise between the resolving power and light output of these panels.

In this work dependences of resolving power of the scintillation panels on the size of ZnSe(Te) scintillator powder particles and the panels thickness was discovered. The data of the light output dependence on the panel thickness and scintillator particle size in a thickness range of 0.1–1 mm were presented. X-ray images of different test objects obtained using scintillation panels based on zinc selenide were shown.

2. Experimental

The objects of study were scintillation panels of variable thickness made in the form of a layer of polycrystalline particles of irregular shape of inorganic scintillator ZnSe(Te) in the optical immersion medium — silicone rubber. Samples of the panels are made by pouring a mixture of powder scintillator and immersion medium in the container which covered with anti-adhesion material.

Resolving power of the scintillation panels was determined by a known method using an apparatus for X-ray image registration (Fig. 1). As a source of ionizing radiation apparatus ISOVOLT Titan E X-ray Generator 160 was used and the measurements of the resolving power was carried out by using a standard test object EN 462-5 Duplex IQI.

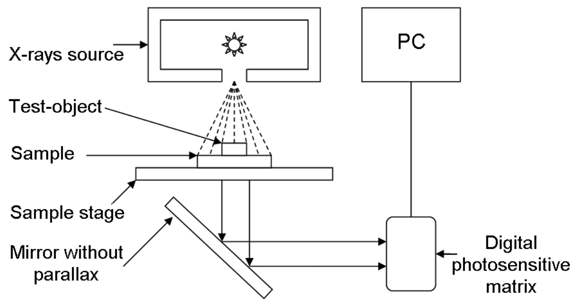


Fig. 1. Scheme of apparatus for X-ray image registration.

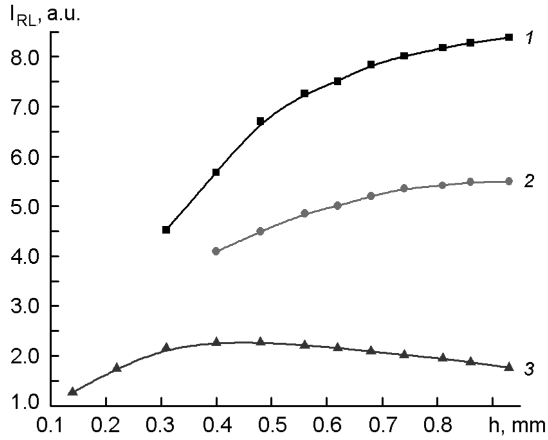


Fig. 2. The dependences of the light yield on the particle size and thickness of the polycrystalline dispersed samples of scintillation panels based on ZnSe(Te). Curve *1* corresponds to the sample of panel with a particles size in 120–200 μm, curve *2* — particles size is 40–120 μm, curve *3* — particles size is 25–40 μm.

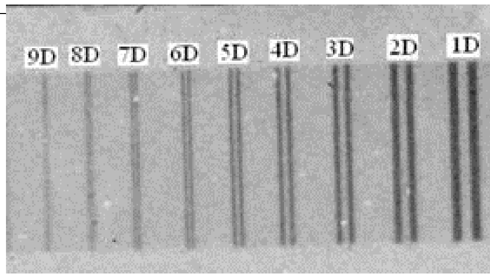
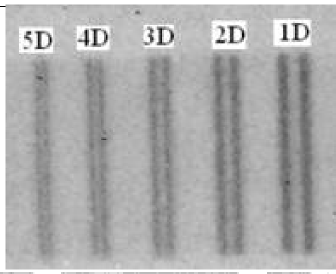
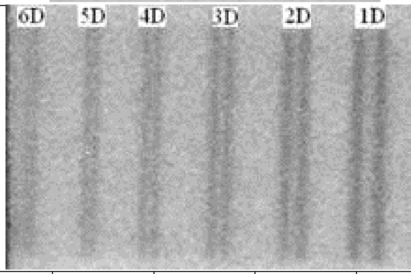
Measurements of the samples light output intensity were carried out by a known method using the unit for measurement of light yield and afterglow — Smiths Heimann AMS-1.

3. Results and discussion

Experimental samples of scintillation panels based on ZnSe(Te) were manufactured with a variable thickness which ranged from 0.1 to 1 mm. Three ranges of particles dispersion were investigated: the first one is 25–40 μm, the second — 40–120 μm, and the third one — 120–200 μm.

The data of dependences of the light yield on the particle size and thickness of

Table 1. The resolving power measurements results for scintillation panels based on ZnSe(Te)

Size of the ZnSe(Te) particles in the panel, μm	X-ray image								
25–40									
40–120									
120–200									
Designation	1D	2D	3D	4D	5D	6D	7D	8D	9D
Diameter of the wire	0.800	0.630	0.500	0.400	0.320	0.250	0.200	0.160	0.130
*l*p/mm	1.25	1.6	2	2.5	3	4	5	6.25	7.69

the polycrystalline dispersed samples of scintillation panels based on ZnSe(Te) are shown in Fig. 2. The first range of dispersion is the minimum allowable for zinc selenide and with further decreasing of particle size the light output becomes ten times lower than the light output of the original crystalline sample. This is due to the electron capture length in zinc selenide (about 30 μm at these energies) and if it becomes greater than the size of the particles then only a minor fraction of X-ray radiation is absorbed by particles and induces scintillation flashes. For the first range of dispersion the maximum of light output is observed at thicknesses from 0.3 to 0.5 mm. With the further thickness decrease of the panel the light output also decreases due to deterioration of the optical transparency of the medium and the dissipative processes of scattering and reabsorption of scintillation flashes in the sample. The second and third ranges of dispersion possess higher light output which according to Fig. 2 increases in the thickness range in 0.1–1 mm and reaches a maximum at thicknesses in 1–1.5 mm for the second range and 1.3–1.8 mm for the third range [4].

For determination of dependences of the resolving power of scintillation panels on scintillator's particle size the samples of three ranges of dispersion were measured (scheme of the experiment is shown in Fig. 1). Scintillation panels made of the first range of dispersion possess the best resolving power — approximately 4–5 lp/mm. Such resolving power value is achieved due to small sample thickness (0.1–0.3 mm) and relatively small particle size of the scintillator (25–40 μm) which form a dense layer of scintillation material and within this layer the scattering of scintillation flashes is minimal. Panels based on ZnSe(Te) powder with a particle size of 40–120 μm have a lower resolving power (3 lp/mm). Resolving power of the scintillation panels with pow-

Table 2. Some characteristics of scintillation panels based on ZnSe(Te)

Size of the ZnSe(Te) particles in the panel, μm	Thickness of the panel, mm	Resolving power of the panel, lp/mm	Relative light output, % from the original crystalline sample ZnSe(Te)
25–40	0.1–0.3	4–5	up to 30
40–120	0.3–0.5	3	up to 55
120–200	0.5–1.5	2.5	up to 80

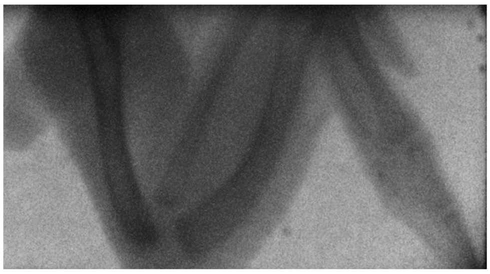


Fig. 3. X-ray image of the biological test object (chicken wing) obtained by using scintillation panel based on ZnSe(Te) with a dispersion of the scintillation particles 120–200 μm.

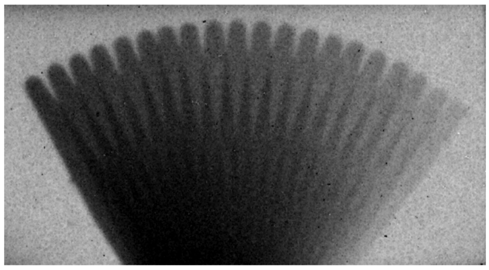


Fig. 4. X-ray image of the inorganic test object (a set of calibrated steel plates with a thickness from 0.05 to 1 mm) obtained by using scintillation panel based on ZnSe(Te) with a dispersion of the scintillation particles 120–200 μm.

der dispersion in 120–200 μm is 2.5 lp/mm (Table 1). The resolving power deterioration for the scintillation panels with increasing of the particles size can be explained by increasing the panel's transparency due to an enlargement of the particles and thus reducing the number of scattering centers and light absorbing surface in the scintillator/immersion medium system. With increase of the panel's transparency the scattering cone of scintillation flashes also increases. The values of resolving power of the scintillation panels based on ZnSe(Te) obtained according to the optimized parameters of X-rays.

Creation of high-quality scintillation panels requires a compromise between the panel thickness (respectively the level of light output) and resolving power, since an increase of the panel's thickness decreases the resolving power by increase of the scattering cone of scintillation flashes. According to studies, the optimal thicknesses of the panels in order to achieve maximum resolving power with saving the light yield at the appropriate level for photodetector are as follows: for the first range of dispersion the optimal thickness belongs to the range 0.1–0.3 mm at the level of light output in 30 % of the original crystal's light yield; 0.3–0.5 mm thickness range is optimal for a second range of dispersion at the light output level in 55 % and 0.5–1.5 mm thickness range is optimal for the third dispersion range with the light yield in 80 % (Table 2).

The images of different test objects were obtained using the scintillation panels based on ZnSe(Te) powder with a dispersion of 120–200 μm. The organic test object (chicken wing) is show in Fig. 3. The photo presents the wing X-ray image where soft tissue, bone tissue and voids in them are visible. By varying the parameters of X-rays (current and voltage of anode) the necessary contrast of images can be obtained. To demonstrate the dynamic range of the scintillation panels a set of calibrated steel plates with thicknesses ranging from 0.05 to 1 mm and a spacing of 0.05 mm was chosen as an inorganic test object (Fig. 4).

According to the X-ray image data even minor change of the object's thickness (0.05 mm) is clearly recorded in the photo that means that scintillation panels based on ZnSe(Te) possess the high sensitivity of detection.

4. Conclusions

As a result of this work the dependences of the resolving power and the level of light output of scintillation panels based on ZnSe(Te) on the sample's thickness and the dispersion range of the particles were determined.

It was found that the scintillation panels based on zinc selenide from the first range of dispersion can be successfully applied in digital radiography for which the requirements for resolving power vary from 0.7 to 4–5 lp/mm. Panels based on the second and third ranges of dispersion according to their characteristics are suitable for the producing of position sensitive detectors such as scintillator-photodiode systems.

Thus the compliance of the optical and scintillation parameters (such as resolving power, dynamic range, sensitivity of detection) of scintillation panels based on ZnSe(Te) for requirements and standards of digital radiography has been demonstrated in this work.

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Роздільна здатність сцинтиляційних панелей на основі селеніду цинку

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Представлено характеристики експериментальних зразків гнучких сцинтиляційних панелей, виготовлених на основі дрібнодисперсних порошків селеніду цинку. Вивчено залежність роздільної здатності сцинтиляційних панелей на основі ZnSe(Te) від розміру часток порошку сцинтилятора і товщини панелей. Представлено дані про залежність світлового виходу панелей від товщини і розміру частинок сцинтилятора для зразків у діапазоні товщин 0,1–1 мм. Показано рентгенографічні знімки різних тест об'єктів, отримані за допомогою сцинтиляційних панелей на основі селеніду цинку. Досліджено три діапазони дисперсності частинок: перший — 25–40 мкм, другий — 40–120 мкм, третій — 120–200 мкм. Встановлено, що роздільна здатність становить 5, 3, 2.5 пар ліній/мм для відповідних діапазонів.