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An inverse method of manufacturing a structured X-ray screen

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Abstract

It is shown that the spatial resolution of an X-ray screen can be increased by forming pore–like matrix filled with phosphor. It is revealed that the smaller is the diameter of the pore, the higher spatial resolution can be achieved. However, there is a problem of filling the narrow pores. In the proposed method, phosphor was mixed with a structured material, the resist SU-8, and the patterning was carried out, using synchrotron radiation of the VEPP-3 synchrotron source. Thus, the need of filling pores with phosphor disappears. Due to the deep penetration of hard X-rays into the materials during the patterning step, in spite of heavy elements inside Gd_2O_2S used as a phosphor, the height of patterned microstructures can be as large as tens or hundreds of micrometers. The optical isolation of the patterned phosphor pillars is carried out by electroplating of nickel between the pillars.

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Keywords: X-ray screen; microstructure; X-ray lithography.

1. Introduction

It was experimentally demonstrated by Kondratiev et al. (2000) that structured X-ray phosphor screens of image intensifiers provide higher spatial resolution than that of continuous screens, due to the small diameter of pores. In addition, the efficiency of structured screens can be improved via increase in the pore length (up to the certain limit, caused by scattering of both primary and secondary radiation), as demonstrated by Badel et al. (2004). With augmentation in the ratio of pore length to its transverse size (so-called aspect ratio), it becomes more difficult to fill the pores with a phosphor, as studied by Kondratiev et al. (2000). Moreover, the quantum yield lessens with decrease in the phosphor grain size, as shown by Rao and Rao (1979). Besides, to ensure a defect-free image it is necessary to uniformly fill the pores with the phosphor. So, the process of filling the pores is an important step in the manufacture

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of structured screens. To avoid direct deposition of phosphor into the pores, it was developed an indirect filling method.

2. Manufacturing

The conventional method of manufacturing a structured screen, proposed by Lubowsky and Swank (1977) consists in forming pores and filling them with a luminescent material, as shown by Daniel et al. (2007). However, exactly this sequence of screen manufacture is associated with the problem of pores filling. We have changed the order of the operations, first forming a luminescent nucleus from phosphor powder fixed with a binder and then covering the nucleus with a nontransparent coating (Fig.1).

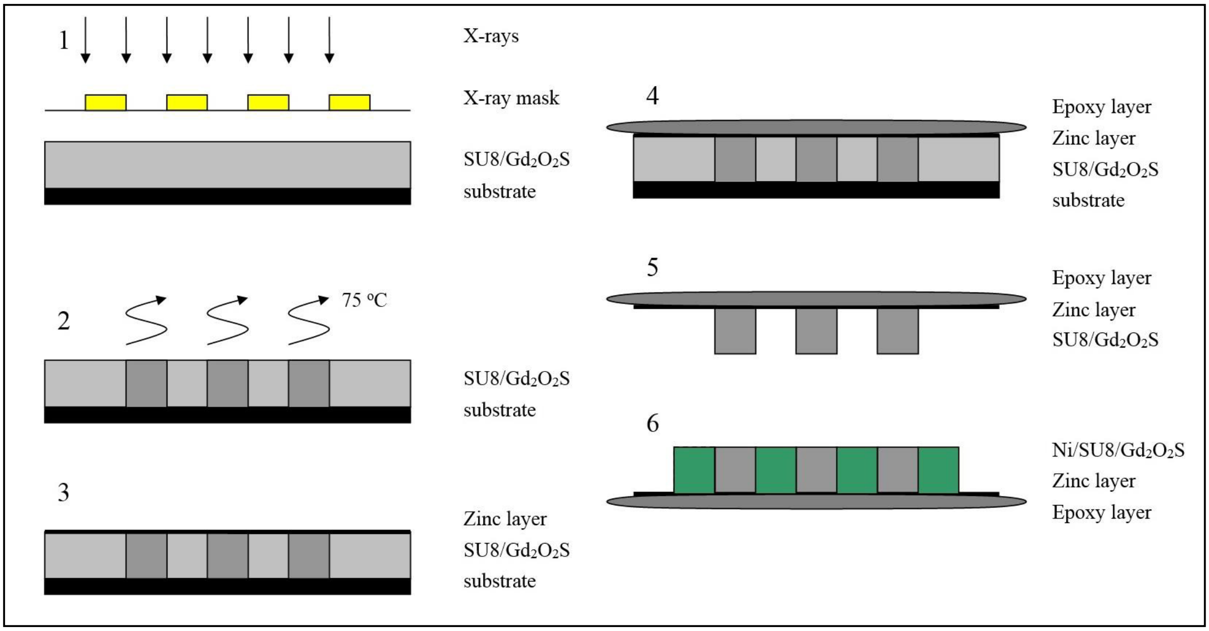

Fig.1. Basic steps in manufacturing processes: 1) Exposure to X-rays; 2) Post exposure baking; 3) zinc layer sputtering; 4) epoxy layer molding; 5) wet development; 6) Ni-electroplating.

The phosphor powder Gd_2O_2S with a grain size in the range of 7 ± 3 µm was mixed with the binder, the photoresist SU8-3025 in this case, with a 4 : 1 mass ratio. The resulting mixture was cast onto a silicon substrate and dried on a hot plate at a temperature of 95ºC, until the solvent concentration reached 3% of the photoresist mass. The soft baked layer was exposed to X-rays at the LIGA beamline of the VEPP-3 SR source, as described by Goldenberg et al. (2016). The initial spectrum of the incoming X-ray beam was corrected by means of metal foils in order to reduce the dose gradient over the depth of the mixture layer. As a result, the maximum of the spectrum of the deposited dose was shifted to a photon energy of about 20 keV. That causes a reducing of the contrast of X-ray mask. In order to keep high contrast, the thickness of the absorber has been increased to 100 µm, as reported by Petrova et al. (2007). Post-exposure baking followed the exposure to X-rays: the layer was heated to 75ºC and held at this temperature for 130 min. Then, the samples were left for self-cooling.

Nevertheless, of the use of hard spectrum, the distribution of deposited dose falls into the resist depths tremendously, due to the high absorption of X-rays with the phosphor. It causes low adhesion of the layer to the substrate, which results in the microstructuring defects. To avoid that, the manufacturing process has been inverted.