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Abstract

Full Text

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A NEW OPTICAL AND CATHODOLUMINESCENT MATERIAL WITH GLASS-FIBER PROPERTIES *

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With the development of electron optics, the range of requirements imposed on cathodoluminophores is steadily expanding. Since cathodoluminescent screens are used in various electron-optical instruments in the study of diverse physical phenomena, new requirements have been added to such characteristics of cathodoluminescent screens as luminous output, resolving power, resistance to irreversible burn-in, afterglow, and luminescence spectra: image contrast, the ability of a screen to transmit an image from one part of an electron-optical instrument to another or from a vacuum into the atmosphere, and certain others. In this connection, new forms of cathodoluminescent screens have appeared: sublimated, then single-crystal, glass, and cathodoluminescent glass fiber.

Fig. 1. Electron microphotograph of the initial stage of formation of crystal fiber. (Cross section)

Crystal fiber. In the course of studying cathodoluminescent glasses, it was found that in some cases crystallization of the glass during heat treatment leads to the formation of thin filamentary crystallites with a high refractive index ($n_D = 1.705$), immersed in a vitreous phase with a lower refractive index ($n_D = 1.481$). This creates conditions for light guiding analogous

light conductivity of glass-fiber products. The best results were obtained in the

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* The work was reported at the XIV Conference on Luminescence (crystal phosphors), held in Riga on September 16–23, 1965.

Fig. 2 and Fig. 3

Figure 2: Fig. 2 and Fig. 3

case of crystallization of glasses close in composition to zinc orthosilicate. As can be seen from the photographs presented (Fig. 1), during heat treatment crystals of zinc orthosilicate are precipitated, growing in a definite direction, namely along the temperature gradient. The photographs were obtained with an electron microscope by the method of one-stage carbon-platinum replicas at an overall magnification of about 10 000×. From the photographs one may conclude that: a) the Zn_2SiO_4 crystals have an elongated prismatic form with a hexagonal cross section; b) a regular, parallel orientation of the crystallites is characteristic;

Fig. 2

Fig. 3

Fig. 2. Cathodoluminescent characteristics of crystal-fiber screens

Fig. 3. Image obtained from a crystal-fiber screen by the method of contact photography

crystallites; c) the total amount of crystalline phase reaches 35%; d) the diameter of the crystals varies from 0.3 to 1.5 µm at the beginning of crystallization; the spread in diameter decreases further during heat treatment; the length of the crystalline needles increases substantially and may reach several centimeters.

Investigation of the resolving power, which can be obtained with screen thicknesses of the order of 2–5 mm, shows that samples with a resolution of 50–100 lines/mm can be obtained without particular difficulty. The contrast of the image transmitted by the crystal-fiber disk reaches 0.8–0.9. It should be noted that the contrast remains high also in photographs made by the contact method, which confirms the large aperture of the crystal fiber (0.85).

Cathodoluminescent crystal fiber. To obtain cathodoluminescent screens, the crystal fiber was made with various activating admixtures. The best results were obtained when manganese was used as the activator. With the optimum activator concentration and optimum heat-treatment conditions, and also with observance of the rules of luminescent cleanliness during preparation of the specimen and its processing, at an accelerating voltage of 30 kV and a current density of $5 \cdot 10^{-8} \div 10^{-7}$ A/cm^2, the light output reached 4–5 cd/W. In the future, the light output can apparently be increased somewhat further by reducing the amount of glassy phase. The dependence of the light output on the accelerating voltage and current density (Fig. 2) does not differ appreciably from those for polycrystalline willemite. It is necessary to note the absence of the so-called dead zone (i.e., absence of luminescence at small accelerating voltages), characteristic of polished single-crystal caiodoluminophores. Luminescence was observed already at accelerating voltages of 100–200 V. The resolving power of the cathodoluminescent crystal fiber depends mainly on the diameter of the crystallites forming the fibrous block.

Studies showed that the best specimens of crystal-fiber screens had a resolution of up to 100 lines/mm. Figure 3 shows an image obtained by contact photography. The diameter of the image on the crystal-fiber screen is 15 mm (cell size 0.5 mm), and the screen thickness is 1.5 mm. It should be noted that the quality of the image in photographs made by the contact method is not much worse than with the ordinary photographic method, while the exposure is tens and even hundreds of times shorter.

The afterglow of manganese-activated crystal fiber depends on the conditions of its preparation and on the amount of activator. The magnitude of the afterglow of the crystal fiber is also regulated by introducing impurities. For specimens optimal in brightness, the decrease in luminescence brightness to 10% of the initial value occurs 0.02–0.03 sec after the electron-beam irradiation is stopped.

The spectrum of cathodoluminescent crystal-fiber screens is a broadened band in the range 480–560 mµ, with a maximum in the region of 530 mµ. The color of the glow is saturated green, characteristic of willemite screens. As is known, willemite also crystallizes in the β modification, which gives a yellow glow. However, it has not yet been possible to obtain crystal fiber with such a luminescence spectrum and good optical characteristics.

Studies of the physicochemical stability of crystal-fiber screens showed their resistance to irreversible burn-in. At a current density of 10^{-8} A/cm^2 and an accelerating voltage of 35 kV, the screens did not reveal any noticeable decrease in luminescence brightness over tens of hours of operation.

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