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The distribution of the polarization degree of the luminescence in rectangular blocks of glass*

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The stresses existing in glasses cause a definite orientation and possibly some deformation of the luminescence centres created by the activators in glass. This orientation of luminescence centres cause a polarization of the light emitted by these centres. The distributions of polarization degree for luminescence were measured along the determined directions in rectangular cubes of glass. It has been pointed out that the stress distribution in glass is correlated with the polarization degree of the luminescence.

Introduction

The polarization of the luminescence radiation may occur, when at least one of the following conditions is fulfilled [1]:

a) the luminescence excitation is anisotropic,

b) the exciting system is anisotropic.

An example of an anisotropic system may be any rigid medium in which the particles are at least partly oriented. The luminescence of such a system is partly polarized even for the isotropic excitations, since the orientation of the transition moments is determined by the type of the crystal field symmetry within the luminescence centre. In the media, in which the luminescence centres are partly oriented, the degree of the luminescence light polarization from these centres is the function of ordering degree of the latters.

The examinations of the luminescence polarization allow to obtain some information concerning the luminescence mechanisms as well as the luminescence centres and their surrounding. This is because the polarization degree of fluorescence depends upon the anisotropic properties of the centre itself as well as upon the depolarizing factors working at the time between the acts of light absorption and emission. Among these depolarizing factors we may mention: energy migration, intermolecular excitation, secondary fluorescence, and molecule vibrations arround their equilibrium positions.

Glass is commonly believed to be an isotropic medium. However, the axial stress evokes anisotropy of the optical properties of glass — its birefringence. The examinations of birefringence carried out by ZARÓWNY [2], and ZARÓWNY and RATAJCZYK [3] have shown that the birefringence distribution in the perpendicular block of glass is conditioned by the sample geometry (the ratio of side lengths $a : b : c$), and not be its dimension (values of a, b, c). It should be expected that the lumines-

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cence centres in glass will take the orientation consistent with distribution of forces acting inside the glass cube, being thereby the reason of partial polarization of the luminescence radiation.

Characteristics of the material examined

The material under test was glass, which included, beside the basic components, some small quantities of activators: cerium and silver. The chemical composition of this glass given in weighting per cents was the following: SiO_2 — 78.0, Al_2O_3 — 7.0, Li_2O — 11.0, K_2O — 4.0, Sb_2O_3 — 0.02, CeO_2 — 0.03, Ag_2O — 0.04. In the glass activated by cerium the luminescence during the optical excitations which occurs due to the Ce^{3+} ions existing in glass. This luminescence is caused by the electron transitions $5d \rightarrow 4f$ in the trivalent cerium ions. The maximum of the luminescence band connected with the cerium ions in glass occurs at about 400 nm. The Ag^+ ions which are present in the glass do not exhibit any photoluminescence in the visible range. However, after the suitable photothermal processing consisting in UV irradiation of the silver-containing glass and next its annealing at the temperature ranging from 423 to 573 K there appear the centres of atomic silver Ag^0 which exhibit fluorescence. The maximum of luminescence band attributed to these centres occurs at about 650 nm. The excitation spectra of luminescence of Ce^+ and Ag^0 centres do not overlap, therefore the luminescences from centres Ce^{3+} and Ag^0, respectively, may be excited independently of each other.

Description of the measuring system

The polarization degree of luminescence has been measured in one of the systems proposed by FEOFILOW [4]. The luminescence has been excited with a non-polarized light from the mercury HBO-50 lamp which was next monochromatized by the set of glass filters matched to the required wavelenght. The parallel light beam exciting the luminescence was limited by the diaphragm of diameter equal to 3 or 1 mm. The spatial distribution of the polarization degree of luminescence has been measured in rectangular cubes of glass of sizes $14 \times 14 \times 30$ mm. The ray of exciting light travelled in three directions within the glass cube and at several different distances from its surface. The polarization degree of the luminescence has been measured in the direction perpendicular to the direction of the exciting light beam and at about 30 points lying along the exciting light beam and distant with respect to each other by no more than 1 mm. The luminescence radiation, after passing through the set of filters and a polarizer, fell onto the photocathode of a multiplier. In order to avoid the influence of the light vector orientation on the photomultiplier sensitivity a depolarizer in the form of a quartz plate of mat surface was placed immediately in front of the photomultiplier window. The polarization degree of luminescence was calculated according to the formula

$$P = \frac{I_1 - I_2}{I_1 + I_2},$$

where I_1 and I_2 denote the values of the photomultiplier current proportional to the respective light fluxes polarized in the mutually perpendicular planes and oriented in such a way that the difference $I_1 - I_2$ be maximized.

The relative measurement error of the polarization degree of luminescence ranged from few to several percents.

Measurement results and conclusions

Very accurate examinations consisting in some hundreds of measurements made for each sample of the examined glass allow to state that the distribution of the polarized degree of luminescence along the definite directions in a rectangular glass cube corresponds to the stress distribution in this glass [2]. It appeared that even for the samples, in which no stresses are detectible by the method of birefringence measurement, the distribution of polarization degree of luminescence corresponds to the stress distribution measured in paper [2].

The exemplified curves illustrating the changes in the polarization degree of luminescence occurring along the longest side of the rectangular cube and measured

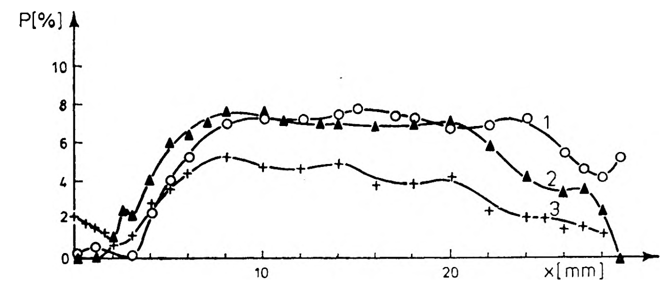

Fig. 1. Distributions of the polarization degree of cerium centre luminescence in glass measured along the longest side of the rectangular cube of glass at the distance *d* form its surface (1. *d* = 1 mm, 2. *d* = 1 mm, 3. *d* = 5 mm)

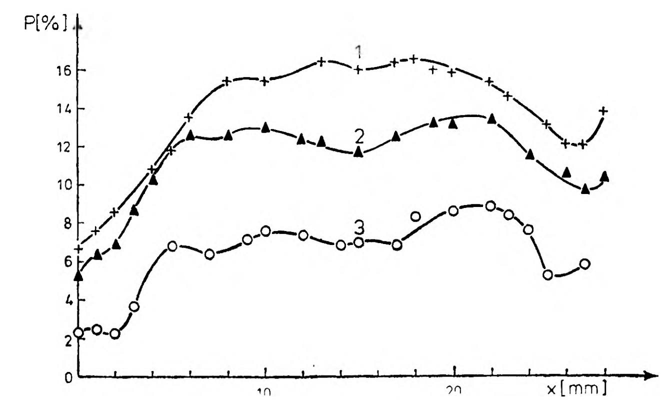

Fig. 2. Distributions of the polarization degree of silver centre luminescence in glass measured along the longest side of the rectangular glass at the distance *d* from its surface (1. *d* = 2 mm, 2. *d* = 5 mm, 3. *d* = 11 mm)

in samples exhibiting no birefringence are presented in figs. 1 and 2. Fig. 1 presents the distribution of the polarization degree for the light emitted by the cerium ion centres in glass, while fig. 2 shows the distribution of the polarization degree of luminescence of atomic silver centres. The similarity of the shape of all the curves represented is striking and it indicates a relatively high degree of directivtiy of luminescence centres in the middle part of the cube.

From the comparison of graphs presented in figs. 1 and 2 it may be seen that the atomic silver centres are more sensitive to the axially acting stress than the luminescence centres associeted with the Ce^{3+} ions. This is understandable if the character of electron transitions responsible for the light emission at each centre is taken into account. In the trivalent cerium ions the $5d \to 4f$ electron transitions, in which the internal orbitals $4f$ are engaged, are accompanied by the luminescence. In the atomic silver centres the situation is more complex. This centre appeared as a result of electron capture by the Ag^+ ions and thus the charge density in this region is greater. Besides, in the electron transitions responsible for the luminescence of the Ag^0 centres the most external shells of silver atoms are involved, which are very sensitive to both the changes in symmetry and the value of the crystal field.

The values of the polarization degree of the light emitted by central part of the sample are always greater than those for the light emitted by the layer close to the surface. Tiny but of macroscopic sizes nonuniformities of glass (bubbles, for instance) change considerably the values of the polarization degree of luminescence. The conclusion that follows is that the values of the polarization degree of luminescence obtained from the measurements made for different glass samples cannot be compared unless the distribution of the polarization degree is measured in each case along the definite direction in the glass cube.

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Распределение степени поляризации люминесценции в прямоугольных призмах стекла

Существующие в стекле напряжения вызывают определённую ориентировку, а быть может, также деформацию центров, образованных ионами активаторов в стекле. Проявлением направленности люминесцентных центров должна быть поляризация излучаемого ими света. Измерялись распределения степени поляризации люминесценции вдоль определённых направлений в прямоугольных призмах стекла. Оказалось, что распределение напряжений в стекле отображается в значениях степени поляризации люминесценции.