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Measurements of visual light scattering in glass electrets

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In the paper the results of examination of visual light scattering in glass samples to which external electric field is applied have been presented. It has been stated that in electret samples the scattering was greater than in samples treated only thermally. On the basis of the light scattering measurements a model of charge distribution in glass electrets is suggested.

1. Introduction

The light scattering in glasses is caused by microheterogeneities. The scattering centres are the liquation regions, crystallites and microcracks. The light scattering phenomenon observed in many glasses differs in an essential way from the typical scattering phenomena occurring in other materials and described by the theories of Rayleigh and Mie. All the phenomena, which cannot be described by any of the above theories, are called anormal scattering.

Instead of a general theory the kinematic approximation [1] is usually used to describe the light scattering. The kinematic approximation of the theory of electromagnetic radiation scattering by nonuniform body consists in determining the resultant (summation) amplitude of light scattered by separate body regions which are treated as dipoles. When summing up, the phase relations between the scattered waves are encountered, the effects of mutual interactions being omitted.

The kinematic approximation has been applied to many simple glasses (like sodium-silicate glasses, for instance). For the glasses of a more complex structure the calculation of correlation function is practically impossible due to its multi-phase and almost unknown structure.

The examinations of light scattering in glasses were carried out mainly in order to control the stages of phase division as well as the changes occurring in glasses under the influence of thermal treatment [2-6].

In this paper, the method of light scattering was applied in order to determine the influence of electric field on the boron-silicate glasses containing two types of alkaline ions.

Earlier examinations [7] pointed out that in glasses of that kind a liquation structure appears. Under the influence of both the electric field and the temperature increase the liquation regions are not only enlarged but also they become polarized. The above phenomena should affect also the change in visual light scattering in the glasses examined.

2. Experiment

Optical glasses of the crown group BK-7 and BK-107 were the object of examinations. They are of the following chemical composition: BK-7 - 68.6% SiO_2, 11.0% B_2O_3, 11.0% Na_2O, 6.0% K_2O, 2.4% BaO, 1.0% As_2O_3, while BK-107 being of the same composition contains additionally 0.2 per cent by weight of CeO_2.

The measurements were performed on the glass cubes of dimensions: 13 x 14 x 30 mm and 10 x 11 x 30 mm (polished), respectively.

From the glasses examined the thermoelectrets were produced by applying an external electric field and by keeping the samples at the 573 K temperature for 5-11 hours.

The block scheme of the setup used is shown in Fig. 1. The setup comprises: 1 - filament lamp, 2 - monochromator, 3 - glass sample, 4 - polaroid for visual light, 5 - photomultiplier, 6 - plotter, 7 - high voltage supplier. The scattering was measured under the angle of 90^{o} with respect to direction of light incidence. In order to determine the error of both the measurement and the method the light scattered by the same sample was measured several times. The difference between extreme values was not greater than 10%.

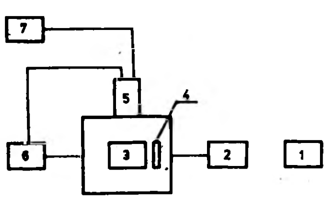


Fig. 1. Block scheme of the setup for the scattered light intensity measurements

3. Measurement results and discussion

Graphs in the Figs. 2 and 3 represent the I/I_0 relation to the wavelength for the electrets of BK-107 and BK-7 glasses, respectively, where I – intensity of the light scattered by the electret, while I_0 – intensity of the light scattered by the glass before creating an electret. The scattering of linearly polarized light was measured. The polarization direction was either perpendicular or parallel to the direction of the applied field (Fig. 4). The intensity of the scattered light polarized in the parallel direction (h) was greater than that in the case of perpendicularly polarized light (v). The light beam was incident on the sample perpendicularly at a distance of 3 mm from its border.

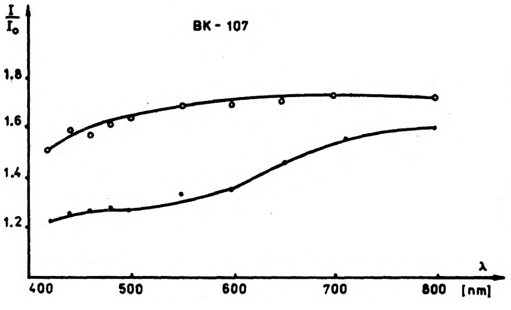


Fig. 2. Dependence of the light intensity scattered by electret of BK-107 glass upon the wavelength. The polarization temperature T_p = 573 K, polarization time t_p = 9 h, external field strength E_p = = $2\cdot10^5$ V/m (o – h, • – v)

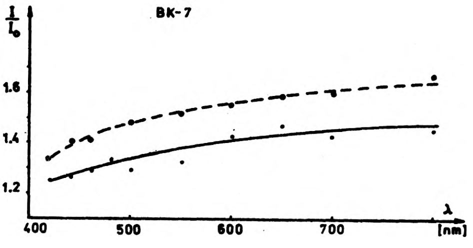


Fig. 3. Dependence of the light intensity scattered by electret of BK-7 glass upon the wavelength. T_p = 573 K, t_p = 9 h, E_p = $2\cdot10^5$ V/m (o – h, • – v)

Because of small value of the light scattered for the wavelength ranging between 420–440 nm as well as that of 800 nm the values I/I_0 for those ranges may suffer from great errors.

Figure 5 displays the intensity distribution of the light scattered by the thermally treated sample of BK-7 glass along the sample. The measurements are performed for the wavelength λ = 600 nm. The ratio I_t/I_0 is presented on the ordinate axis, where I_t – the intensity of the light scattered by the thermally treated sample,

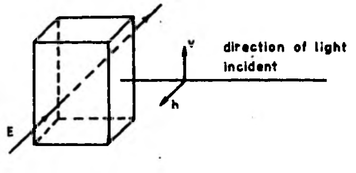
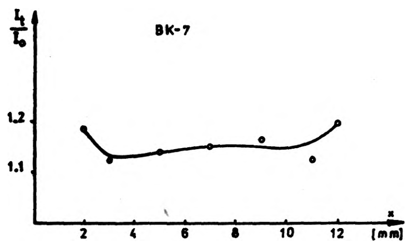


Fig. 4. The direction of both the applied external electric strengths and the ray polarized in the glass sample

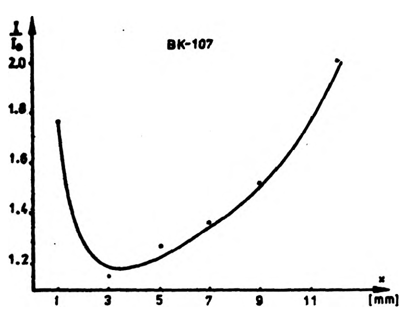


while I_0 – the intensity of the light scattered at the same place of the sample before its treatment.

Fig. 5. Intensity distribution of the light scattered by the sample of BK-7 glass, after thermal treatment, along the sample (λ = 600 nm)

As a consequence of the thermal treatment an increase of scattered light intensity was observed, this effect being the strongest for the regions positioned close to the sample edge. The ratio $I_t(r)/I_0(r)$ does not exceed 1.2. The thermal treatment causes an increase of liquation areas [7], which results in an increase of the scattered light intensity (Fig. 5). This may be also caused by the microcracks occurring during the sample treatment. Such microcracks are very likely to occur during the sample cooling, due to different values of the respective thermal expansion coefficients of the liquation region and of the matrix.

Figure 6 shows the intensity distribution of the light (λ = 600 nm) scattered along the sample produced by electret of BK-107 glass. The intensity distribution of the light scattered by electret of BK-7 glass is similar. Both for BK-7 and BK-107 glasses the electric field operation was limited to about 3 mm depth in the sample. In the sample middle the scattered light intensity is close to the value obtained for samples subject to thermal treatment only.



The changes in scattering under the influence of electric field may be caused by several effects. In the course of electret formation free charge carriers may appear due to thermal excitation. At the pres-

Fig. 6. Intensity distribution of the light scattered by the electret of BK-107 glass along the sample (λ = 600 nm). T_p = 573 K, t_p = 11 h, E_p = $2 \cdot 10^5$ V/m

ence of external electric field the charge carriers may move and be captured by the defects located on the border surfaces of the liquation regions. Dipoles are created in the liquation regions as a result of the external field action and the raised temperature and subsequently due to migration of alcali ions. There is a high probability that the ohaŕge carriers will be captured in the regions in whioh a local electric field appears and thus at the opposite borders of the liquation region in the direotion of the acting electrio field.

Besides, the charge may be collected on the miorooraks surfaoes. The charge collected on microcraks and on the borders of liquation regions causes an increment of the scattered light intensity.

The presented results of examinations indicate that by applying the light scattering method it is possible to determine the model of the space charge distribution in the glass electret. It seems that on the base of these examinations it will be also possible to determine the eleotric field distribution in a sample formed in this way. This problem will be examined further.

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ИЗМЕРЕНИЯ РАССЕЯНИЯ ВИДИМОГО СВЕТА В СТЕКЛЯННЫХ ЭЛЕКТРЕТАХ

Приведены результаты исследований рассеяния видимого света в стеклянных образцах, подвергнутых действию внешнего электрического поля. Было выявлено большое рассеяние в электретовых образцах по сравнению с образцами, подвергнутыми только термической обработке. На основе измерений рассеяния света предложена модель распределения зарядов в стеклянном электрете.