Photoinduced gyrotropy and photoinduced light scattering in the chalcogenide glass As_2S_3

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Some new photoinduced effects, specifically, a circular dichroism and an intense light scattering, have been observed during the exposure of bulk samples of the chalcogenide glass As_2S_3 to intense light with $h\nu < E_g$ from a He–Ne laser. These effects suggest that an interaction of light with $h\nu < E_g$ with weak links of the glass is manifested in the nucleation of anisotropic and gyrotropic scatterers.

A photoinduced anisotropy of the chalcogenide glass As_2S_3 was reported in Ref. 1. The large photoinduced optical activity and the conversion of linearly polarized light into elliptically polarized light which were observed in that study cannot be explained on the sole basis of a linear dichroism and a birefringence, which are manifestations of a photoinduced anisotropy. These effects suggest that the photoinduced anisotropy in the test samples should be accompanied by a photoinduced gyrotropy (circular dichroism and circular birefringence). This suggestion has been validated, and we are reporting the first results of a study of the photoinduced gyrotropy in the present letter.

In the experiments we used the same bulk samples and the same experimental apparatus as in Refs. 1–3. The application of a constant voltage or of voltage pulses of a certain magnitude to the electrooptic modulator of the apparatus made it possible to produce not only linearly polarized light but also circularly polarized light (left-hand or right-hand) at the exit from the modulator. Curve *1* in Fig. 1 shows the time evolution of the appearance of, and changes in, the transmission gyrotropy induced by linearly polarized light of high intensity (~ 5 W/cm^2): $2(I_r - I_l)/(I_r + I_l)$, where I_r and I_l are the intensities of the low-intensity transmitted light having the right-hand and left-hand circular polarizations, respectively, upon incidence on the sample.

We see that the test sample of the As_2S_3 glass is characterized by an initial, very small transmission gyrotropy (this gyrotropy changes in both magnitude and sign from one part of the sample to another). Exposure to linearly polarized light causes the transmission gyrotropy to change sign and to increase to substantially higher levels.

According to the expression$^{1)}$ $2(I_r - I_l)/(I_r + I_l) = \beta h$, the transmission gyrotropy is determined by the circular dichroism β, which includes both the absorption dichroism and the scattering dichroism. An even larger transmission gyrotropy was induced by circularly polarized light (curve 2 in Fig. 1).

To the best of our knowledge, we are reporting here the first observation of a photoinduced gyrotropy, in particular, a photoinduced circular dichroism, in a glass.

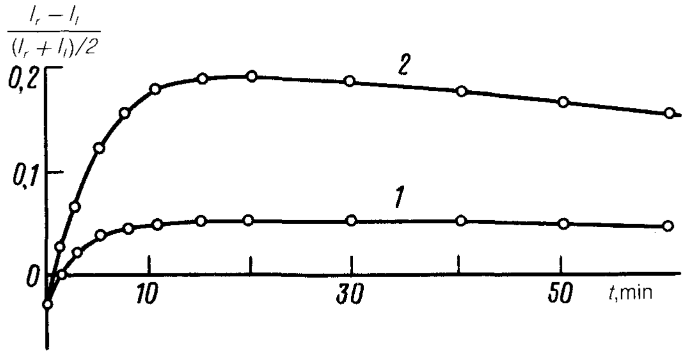

FIG. 1. Kinetics of the photoinduced gyrotropy in the transmission during exposure of an As_2S_3 sample ($E_g = 2.3$ eV) 2.5 cm thick to (*1*) linearly polarized light and (*2*) circularly polarized light from a He–Ne laser ($h\nu = 1.96$ eV).

In the course of the experiments we also observed the appearance of a strong photoinduced scattering of light with a phonon energy $h\nu < E_g$. This effect was manifested primarily in a change in the shape of the laser beam (observed on a screen) transmitted through the glass sample. In the initial stages, the image of the transmitted

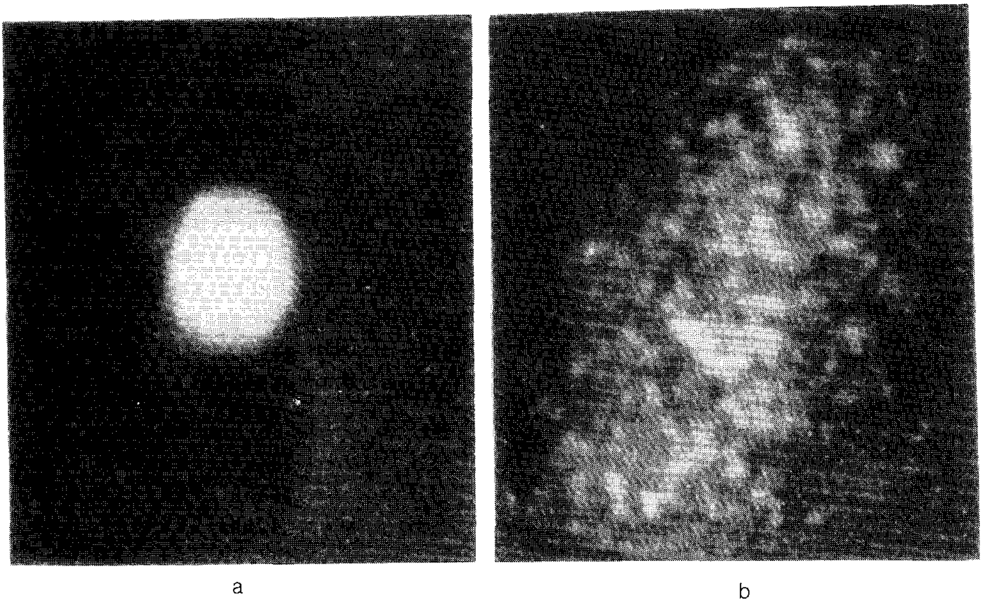

FIG. 2. Image on the screen of a laser beam transmitted through a sample (a) in the initial stage of the exposure to the light and (b) in the final stage.

beam on the screen remains circular; a halo appears and grows over time. The circular image of the laser beam subsequently is smeared out completely, and a distinct speckle appears (Fig. 2).

Qualitative data on the photoinduced light scattering were obtained in experiments in which either the central or peripheral part of the transmitted light beam was directed to the entrance window of the photodetector. The central and peripheral parts determine the light transmitted in the forward direction and the scattered light (scattered through an angle ⩽20°), respectively. This separation of beams was carried out by means of diaphragms and a converging lens. The results of these experiments, shown in Fig. 3, demonstrate that the intensity of the light transmitted in the forward direction decreases over time (curve *1*), while the intensity of the scattered light increases (curve *2*).These results are unambiguous evidence of a large photoinduced change in the scattering function. They also support the assertion that the decrease in the intensity of the scattered light which was observed in Ref. 1 was a consequence not of an increase in the absorption coefficient (a photodarkening) but of an increase in the scattering. This conclusion is also supported by the circumstance that the insertion of a converging lens without diaphragms between the sample and the photodetector (in this case, both the beam transmitted in the forward direction and the beam scattered through an angle ⩽20° are incident on the photodetector) resulted in a substantial reduction of the change over time in the intensity of the light incident on the entrance window of the photodetector (curve 3 in Fig. 3).

The fact that a photoinduced scattering of light occurs is directly related to the partial depolarization of the light transmitted through an As_2S_3 sample which was observed in Ref. 1. The reason for the photoinduced depolarization is that the scattering is caused by anisotropic (or gyrotropic) photoinduced scatterers. The creation of such scatterers should evidently lead to a change in the scattering function.[4]

Vancu *et al.*[5] had previously pointed out the important role played by scattering in the attenuation of long-wavelength light ($h\nu \leqslant E_g$) in chalcogenide glasses which

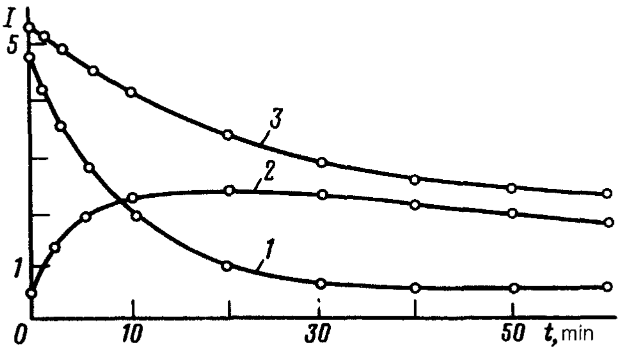

FIG. 3. Intensities of (*1*) the light beam transmitted in the forward direction, (*2*) the light beam scattered at an angle ⩽20°, and (*3*) the sum of these beams, versus the exposure time.

were not exposed to light. They also pointed out that the intrinsic scatterers in these glasses are anisotropic. The data of that study are supported by our own results regarding the difference in the transmitted light on curves *1* and *3* in Fig. 3 in the early stage of the process. The chalcogenide glasses are thus characterized not only by the presence of anisotropic scatterers in the initial state, as synthesized, but also by a photoinduced production of a far greater number of anisotropic and gyrotropic scatterers, which determine the optical properties of the glasses in the region $h\nu < E_g$.

The observation of an intrinsic gyrotropy, a photoinduced gyrotropy, and a photoinduced scattering in chalcogenide glasses raises some new problems in the research being carried out on their structure in order to detect spiral structural elements similar to the structural fragments of organic materials, for which optical gyrotropy effects are characteristic.[6,7]

[1)] A similar expression for the case of a linear dichroism was derived in Ref. 2.

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