

Photoinduced Anisotropy of Photoconductivity in Amorphous $\text{As}_{50}\text{Se}_{50}$ Films

V. Lyubin,¹ M. Klebanov,¹ and V. K. Tikhomirov^{1,2}

¹Department of Physics, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel

²Division of Materials, Wolfson Building, University of Nottingham, NG7 2RD, United Kingdom

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We show that photoinduced optical anisotropy in amorphous $\text{As}_{50}\text{Se}_{50}$ films is accompanied by photoinduced anisotropy of photoconductivity while both photoinduced effects are optically reversible. We suggest that microanisotropic fragments which are the feature of amorphous chalcogenide films do affect not only the light absorption but also the transport of nonequilibrium charge carriers.

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Photoinduced optical anisotropy in chalcogenide glasses is of great current interest [1–8]. The anisotropy gradually appears in the course of irradiation of samples by linearly polarized light, and it can be multiple reoriented when changing the direction of the electrical vector of inducing light between two mutually orthogonal states. This effect is interesting from a fundamental point of view [1–8] and for application in electrooptics [9,10]. Different mechanisms for photoinduced anisotropy were proposed [1–5], among which the mechanism, based on the polarized light induced alignment of randomly oriented structural elements centered at charged valence alteration pairs, can be mentioned [3,5].

In this Letter, we demonstrate that photoinduced optical anisotropy in amorphous $\text{As}_{50}\text{Se}_{50}$ chalcogenide films is accompanied by photoinduced anisotropy of photoconductivity while both photoinduced effects are optically reversible.

Amorphous $\text{As}_{50}\text{Se}_{50}$ films of thickness 0.3–2.0 μm were prepared by a conventional vacuum evaporation technique. Detailed studies [1] indicated photoinduced optical anisotropy and its optical reversibility in these films.

An optical setup employed two linearly polarized laser beams (inducing and probe beams) illuminating the same area of the film [11]. An intense beam of either a He-Ne laser ($P = 2.75 \text{ W/cm}^2$, $\lambda = 633 \text{ nm}$) or an Ar^+ laser ($P = 0.4 \text{ mW/cm}^2$, $\lambda = 633 \text{ nm}$) was used as a probe beam. Photoinduced dichroism, D , which is a measure of photoinduced optical anisotropy, is defined by the relationship $D = 2(J_y - J_x)/(J_y + J_x)$, where J_y and J_x are intensities of the probe beam passed through the film and polarized in two orthogonal directions y and x . The inducing beam was linearly polarized in either the y or the x directions (E_y or E_x) due to rotation of the half-wave plate. Thus, the inducing beam always coincides with either a horizontal or a vertical direction of electrical vector of the probe beam. More details about an optical installation and measurement technique can be found in [1,12].

A setup for the study of photoconductivity employed one linearly polarized beam of either a He-Ne laser ($P = 2.75 \text{ W/cm}^2$, $\lambda = 633 \text{ nm}$) or an Ar^+ laser ($P = 0.3 \text{ W/cm}^2$, $\lambda = 488 \text{ nm}$) which was used for cre-

ating anisotropy at the same time for the generation of photocarriers. Anisotropy of photoconductivity was measured using films with evaporated golden electrodes, as is shown in Fig. 1. The space between parallel electrodes 1–2 and 2–3 was 50 μm . The electric circuit was equilibrated by moving the nonpolarized beam (shown as a circle in Fig. 1) until the nanoammeter G read a zero current. Irradiation with a linearly polarized beam with an electric vector parallel either to 1–2 or to 2–3 electrodes resulted in a differential current detected by a nanoammeter. That current and its sign indicated that photoconductivity became dependent on mutual orientation of electrodes and direction of polarization of light (anisotropy of photoconductivity in the irradiated area). A three-electrode setup shown in Fig. 1 was proven to be much more sensitive as compared with a simple two-electrode setup, which was also used in preliminary measurements.

Figure 2 shows a typical kinetics of photoinduced dichroism in 1 μm thick $\text{As}_{50}\text{Se}_{50}$ film. The measurement was carried out in the area of the film which was free from electrodes. While a nonpolarized inducing He-Ne laser beam did not produce photoinduced anisotropy, the

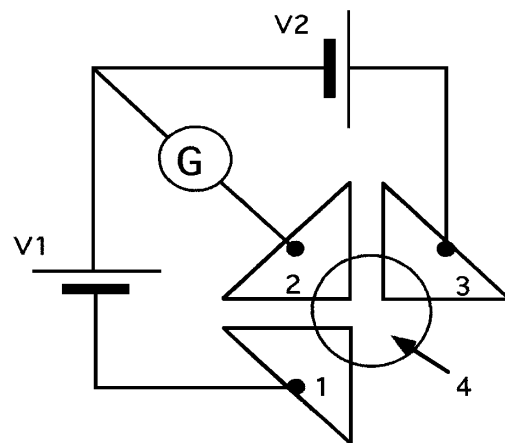


FIG. 1. Layout of electrodes and electrical circuit for the measurement of anisotropy of photocurrent. 1, 2, and 3 are the golden electrodes, 4 is a laser beam, G is a nanoammeter, and $V1$ and $V2$ are the voltage sources.

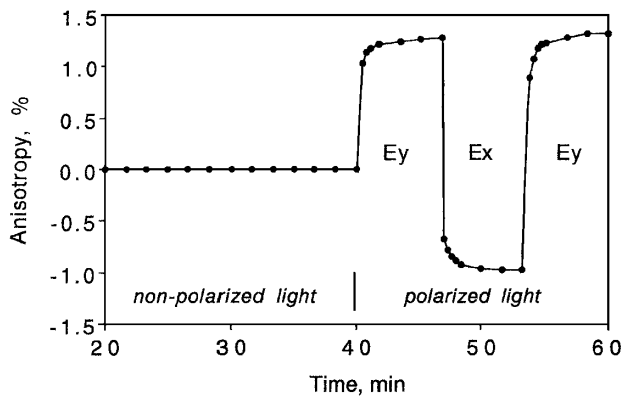


FIG. 2. Kinetics of photoinduced dichroism following the change of the polarization state E of the inducing beam of He-Ne laser.

linearly polarized beam induced a linear dichroism. The sign of photoinduced dichroism was changed following the change in the direction of the electric vector of the inducing beam to the orthogonal one, as it is represented by alternating kinetics in Fig. 2.

Figure 3 shows the data on anisotropic photoconductivity. When the sample with two parallel electrodes was irradiated by a nonpolarized He-Ne laser beam (a laser spot was set between electrodes), we detected the appearance and subsequent saturation of photocurrent (Fig. 3a). Irradiation by linearly polarized light with an electric vector E either parallel, E_x , or orthogonal, E_y , to electrodes re-

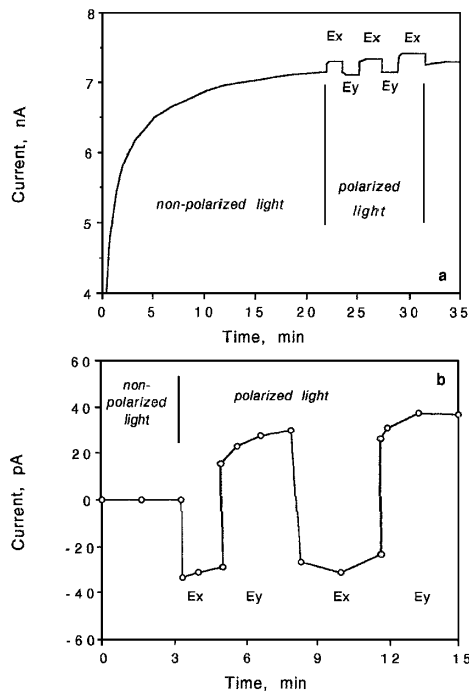


FIG. 3. Kinetics of photocurrent following the change of the polarization state E of the inducing beam of a He-Ne laser in (a) a two- and (b) a three-electrode scheme. E_x and E_y are electrical vectors of excited light parallel and orthogonal to the electrodes in a two-electrode scheme.

sulted in the appearance of anisotropy of photocurrent (see kinks in Fig. 3a).

A three-electrode scheme (Fig. 1) allowed us to detect the anisotropy of photoconductivity in more detail. Figure 3b shows that irradiation of a sample by the intense linearly polarized beam resulted in a current in the circuit of Fig. 1, which was a differential current between 1–2 and 2–3 electrodes. A change in the polarization state of the inducing light resulted in the respective change of the sign of the resultant current. Kinetics of the change of the resultant current was similar to the kinetics of reorientation of the optical dichroism (compare Figs. 2 and 3b). Qualitatively similar results were obtained when using the intense linearly polarized Ar⁺ laser beam.

One would doubt that the observed change of photocurrent in Fig. 3 is due to photoinduced anisotropy of photoconductivity because the current might also appear due to a subtle shift (drift) of the laser beam relative to electrodes. In order to reject this possibility, we carried out an experiment with the films CdSe where photoinduced optical anisotropy is not observed. 1.0 μm thick CdSe films were prepared by vacuum evaporation. Large photoconductivity is a property of these films. Irradiation by the nonpolarized He-Ne laser beam resulted in a gradual increase of the photocurrent up to 400 times. However, irradiation of CdSe films with a linearly polarized He-Ne laser beam with either E_x or E_y polarization did not result in any change of optical absorption or in the appearance of anisotropy of photocurrent in the scheme of Fig. 1. This result rules out an effect of laser beam instability (drift) on the data presented in Fig. 3 regarding anisotropy of photoconductivity in $\text{As}_{50}\text{Se}_{50}$ films.

To the best of our knowledge, we report a first observation of photoinduced anisotropy of electrical properties and its optical reversibility in chalcogenide films. Since photoconductivity σ_{ph} is defined as a product of the concentration of photoexcited charge carriers n_{ph} and their mobility μ ($\sigma_{\text{ph}} = en_{\text{ph}}\mu$, where e is the electronic charge), either of these parameters can be responsible for the observed photoinduced anisotropy of photoconductivity. However, in the scheme of Fig. 1, n_{ph} is obviously the same for the currents between electrodes 1–2 and 2–3, because the same laser beam is used for the generation of photocarriers and resulting currents.

Hence we conclude that the observed anisotropy of photoconductivity is due to different transport properties (mobility) of charge carriers in their movement in a direction parallel or orthogonal to the electrical vector of inducing light. Therefore we observed photoinduced anisotropy of carrier mobility μ ($\mu_x \neq \mu_y$). We note an optical reversibility of photoinduced anisotropy of carrier mobility μ as this is reflected in alternating kinetics in Fig. 3b.

The obtained data indicate that the microanisotropic species, such as charged valence-alternation pairs, affect not only the light absorption process [1] but also the process of transport of the nonequilibrium charge carriers

(mobility of these carriers). While normally these microanisotropic species are oriented randomly, which results in the isotropic photoconductivity, irradiation with the linearly polarized light results in alignment of these species and respective anisotropic photoconductivity.

We showed that photoinduced optical anisotropy in the amorphous $\text{As}_{50}\text{Se}_{50}$ films is accompanied by photoinduced anisotropy of photoconductivity. The anisotropy of photoconductivity is optically reversible, similar to the optical reversibility of photoinduced optical anisotropy. The data obtained indicate that microanisotropic species in chalcogenide glassy films, such as valence-alternation pairs, do affect not only light absorption but also the properties of transport of the nonequilibrium charge carriers.

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