Photoinduced, thermo-reversible and irreversible transformations, and accompanying mechanical transformations in thin As2S3 glass films

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Abstract: Thermally reversible and irreversible photoinduced structural transformations in thin films of As2S3 chalcogenide glass were studied. As a concomitant result, possible mechanical transformations under thermal action are shown, which are resulted in three main types of cracks.

In this work, photoinduced transformations in thin As_2S_3 glass films were investigated. This material, in view of many features, is a good model material for such studies. Although a large number of papers have been published on this topic, including monographs (see, for example, [1]), we will show here the kinetics of illumination and heating-cooling by means of ellipsometric measurements. The study of thermal transformations has shown that under certain annealing regimes, cracks form in the films, the shape of which is surprisingly exactly the same as the theory described in [2].

For the present studies, we previously obtained films 2-5 microns thick by evaporation of the crushed glass under vacuum at a residual pressure of 10^{-4} Tor from an open evaporator. We used substrates in the form of round plates of fused quartz with thickness 1.5 mm and diameter 3 cm.

The dependence of the reversibility of photoinduced transformations on the energy of the quantum of the active radiation is confirmed. Thus, for an annealed sample of a film of thickness 2 μm, the use of a green solid-state laser (530 nm) of relatively high power 100 mW leads to reversible changes. In Fig. 1 (a) shows a graphical diagram of this process. For measurements, a hand-held LEF-3M1 ellipsometer equipped with a laser at a wavelength of 633 nm was used. It should be noted that a simple calculation of optical parameters does not lead to a deep understanding of the processes occurring. In this connection, a technique was used to determine the optical parameters and the thickness of the film in the anisotropic film approximation from in situ measurements [3, 4].

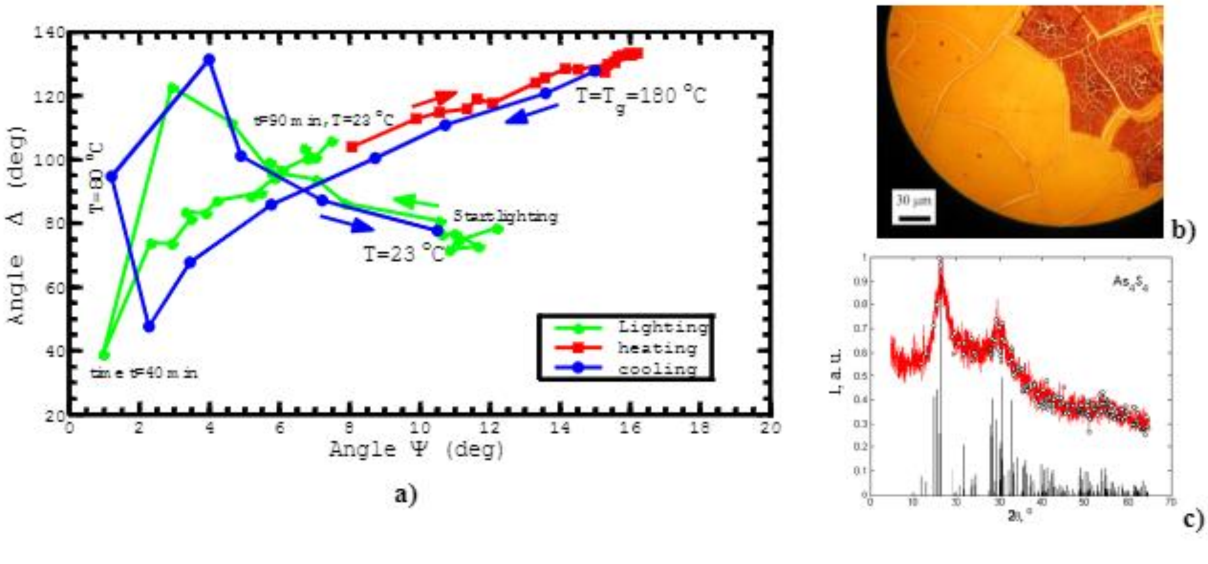

Fig. 1. a) Graphic diagram of the illumination (green segments with asterisks), heating (red segments with squares), and cooling (blue segments with mugs); some values of time and temperature are indicated in the directions of the arrows on the graphs; b) a photograph through an optical microscope of a lighted and heated film (a bright region is not illuminated, a dark one is illuminated); c) X-ray diffraction spectra: a red sawtooth spectrum - a lighted film, a line spectrum - a crystal; points indicate the values of the film spectrum for non-zero values of the spectrum of the crystal.

If we use more rigid radiation for illumination, then the changes will be thermally irreversible. The figure 1 (b) shows the area of the irradiated film using a mask: the dark part is irradiated, the light part is not irradiated. We applied the illumination with blue light from an LED with a power of only 2 mW and a wavelength of 467 nm for 40 min. The characteristic cracks after heating both in the irradiated and in the non-irradiated region indicate a probable relationship between heating and the crystallization process. To confirm this, we compared the X-ray scattering spectrum from the sample shown in Fig. 1 (b) and from the spectra of possible crystalline phases in the As-S system. The most preferred, as it turned out, is a coincidence not with crystal As_2S_3, but with crystal As_4S_4, Fig. 1 (c).

Characteristic cracks in a film of thickness 5 μm, which are visible in Fig. 1 (b), were then obtained for a non-illuminated film of thickness 2 μm, Fig. 2 (a). This kind of cracks as we called a mosaic with T-joints. Striking here is the fact that curvilinear cracks form a right angle at convergence points. Two other types of cracks, the spiral and crests of the crescents, are shown in Fig. 2 (b, c), respectively. The corresponding three types of cracks considered in Ref. [2] are shown in Fig. 2 (a, b, c). In conclusion, we note that the present studies more likely suggest a direction for further research than exhaust the problem. It seems, considering the strength of adhesion, the thickness of films, etc. not enough for the full model. From our point of view, an essential role is played by the so-called pre-crystallization. In Fig. 2 (b, c) is clearly visible, a certain beginning of the crack curve is a microcrystallite.

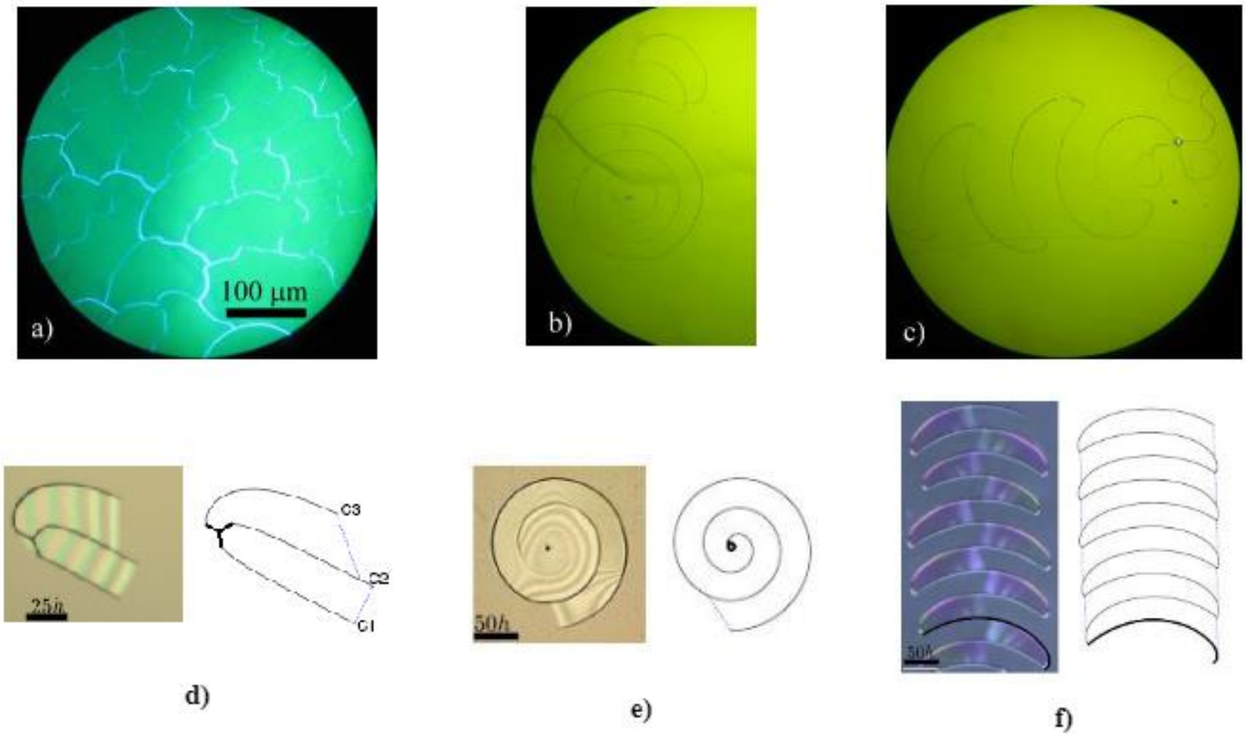

Fig. 2. Photos of typical cracks in thin films thick in an optical microscope (a, b, c) obtained in this paper:
a) a mosaic in the form of a graph, each node of which is formed by a T-shaped elementary graph;
b) a spiral crack;
c) half-moon crests;
d), e), and f) images and schemes of cracks in Ref. [2]. Here the scale is shown in the scale of the film thickness h.

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