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Photoinduced changes of optical reflectivity in As_2S_3-Al system

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Photoimpact on As_2S_3 films results the modulation of optical refractive-index accompanied by the modification of interference conditions for light in thin layers. To increase the value of optical reflection amplitude between interference maximum and minimum the amorphous As_2S_3 films were obtained by thermal evaporation in vacuum onto glass substrates preliminarily coated with aluminium. The monitoring of the reflectivity at wavelength of 532 nm during the evaporation process of As_2S_3 layer allowed to obtain the As_2S_3-Al pattern with initial reflection value of 10-15%. The samples during the experiment were exposed to the light with wavelength of 532 nm with different intensity. An increase of reflectivity up to 75% was observed. This paper presents the studies of dependence for photoinduced changes in reflectivity of As_2S_3-Al system on exposure time, light intensity and film thickness. The holographic recording in reflection mode was performed and studied.

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Keywords: Amorphous chalcogenide films, Reflectivity of the system, Holographic recording

1. Introduction

For the past 10 years the research into the field of optical materials based on amorphous chalcogenide semiconductors has made significant advances. However, despite the intense research into these materials, we are surely still far from knowing everything. New properties are continuously being discovered, leading to new hopes for potential applications.

Now chalcogenide glasses are widely used in technological applications such as infrared optical elements, optical switching devices, holography recording media etc. [1-6]. The chalcogenide glasses are semiconductors with bandgap of 1 – 3 eV and are infrared transmitting, so As_2S_3-Al system can find practical application in the field of adaptive optics in IR region. The field of our scientific group's investigation is the study of impulse dot-matrix holographic recording on As_2S_3-Al reflection system [7]. The main advantage of this type of system is the possibility to receive highly sensitive material for relief-phase hologram recording in predefined parts of optical spectra. Also, the creation of wave-guides and reflection phase masks based on chalcogenide interference system in IR area with the help of a scanning confocal microscope is an interesting field of scientific research. That is why our attention has been attracted to the study of the very optical properties of As_2S_3-Al system. In the present paper we report about some new results of the study of the reflection interference system based on As_2S_3 thin films.

2. Experimental

As_2S_3 films were obtained by thermal vacuum evaporation onto BK-7 glass substrates preliminarily coated with aluminium. The monitoring of film thickness was carried out during the process of evaporation with interference technique at wavelength of 532 nm. The control over the interference minimum of reflection during the evaporation process allowed to obtain As_2S_3-Al system with a minimal initial reflection value (Fig. 1). Process of evaporation was stopped immediately as soon as the interference minimum of reflection was achieved.

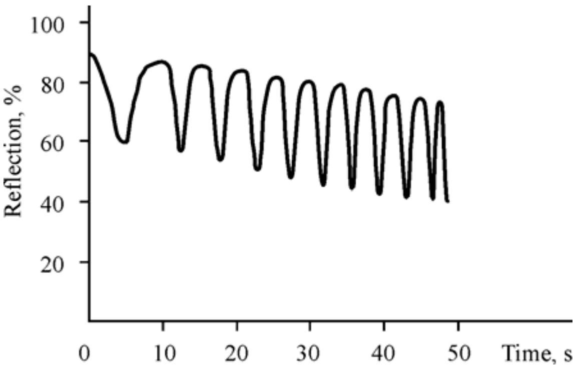

Fig. 1. The modulation of reflection of As_2S_3-Al system during the process of evaporation of 1.1 μm thick As_2S_3 film.

The reflection spectra of all samples was checked (using a tool Ocean Optic Spectrometer HR4000) which proved the minimal value of reflected signal at wavelength of 532 nm. Fig. 2 presents the reflection spectrum of As_2S_3-Al system with layer thickness of 1.1 μm and the dependence of the initial reflectivity of the system on the film thickness at wavelength of 532 nm.

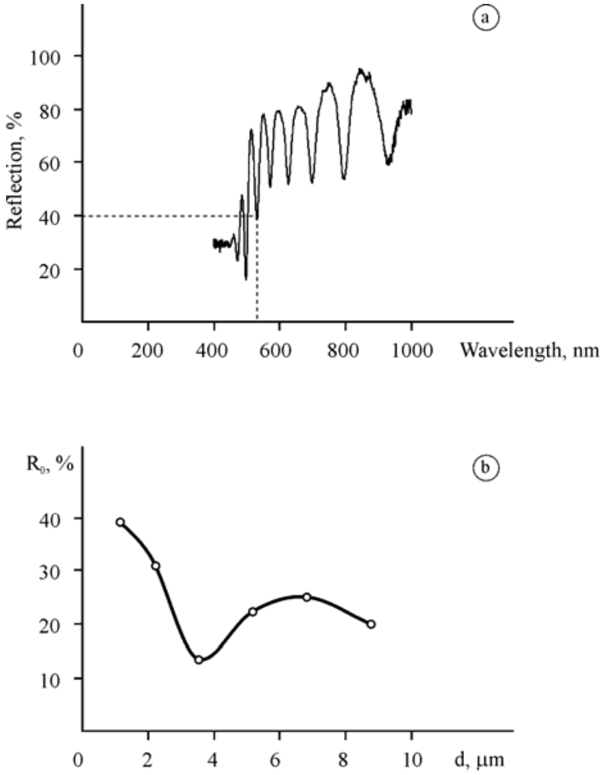

Fig. 2. Reflection spectrum of As_2S_3-Al system with As_2S_3 layer thickness of 1.1 μm (a) and the dependence of initial reflectivity on the film thickness at wavelength of 532 nm (b).

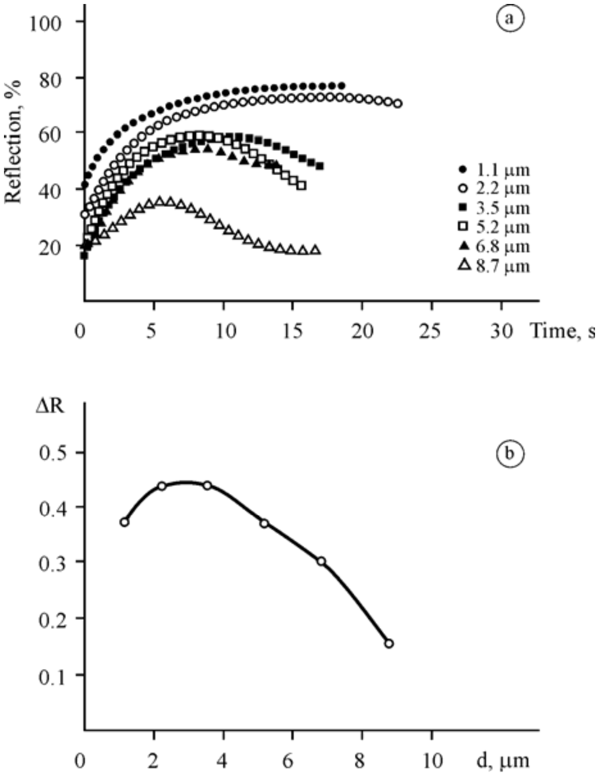

Fig. 3. The dependence of reflectivity of As_2S_3-Al system on the exposure time for the films with different thickness with similar radiation intensity I = 1.6 W/cm^2 (a) and the dependence of modulation of the reflectivity of the system on the film thickness (b).

3. Results and discussion

The samples were exposed by laser at wavelength of 532 nm with intensity of 0.3 – 2.4 W/cm^2. Since the film has uneven thickness because of the peculiarities of evaporation, the place with minimal reflectivity was detected with the help of initially attenuated laser beam. And then the recording was performed. The photoimpact of laser irradiation causes the modulation of optical refractive-index which brings about the modification of interference conditions, that is the modification of reflectivity coefficient of As_2S_3-Al system [8-10]. Fig. 3a presents the dependence of reflectivity of As_2S_3-Al system on exposure time for films with different thickness with similar radiation intensity (I = 1.6 W/cm^2). With film thickness of 2.2 – 3.5 μm the modulation reaches maximum reflectivity and mounts to 45% (Fig. 3b).

Fig. 4 shows the dependence of photosensitivity of As_2S_3-Al system (S, cm^2/J) on As_2S_3 layer thickness (d, μm). Maximal sensitivity is observed in films with thickness 3.5 μm and it amounts to 0.08 cm^2/J.

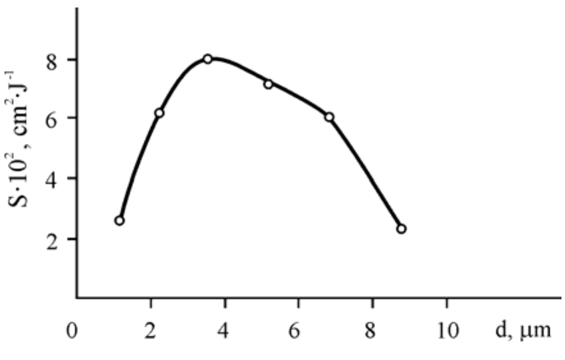

Fig. 4. The dependence of sensitivity of As_2S_3-Al system on As_2S_3 film thickness with similar radiation intensity I = 1.6 W/cm^2.

To compare the photoimpact of different intensity on As_2S_3-Al system the following experiment was made. As_2S_3-Al film with As_2S_3 layer thickness of 2.2 μm was exposed to light of different intensity.

Fig. 5 presents the dependence of reflectivity (R) on exposure time (t) of the sample with As_2S_3 layer thickness of 2.2 μm with different intensity of the recording light. It is clear to see that the reflected signal increases from 30 to 75% with all intensities, but these changes occur during different time intervals: from several seconds with high intensity (12 seconds at 2.4 W/cm^2) to several tens of seconds – with low intensity (~70 seconds at 0.4 W/cm^2). At the same time the sample gets the same quantity of energy $E = I_0 \cdot t$. Therefore, the exposure of the sample to the light of different intensity causes similar modulation of the reflected signal. In our case this modulation is 45%.

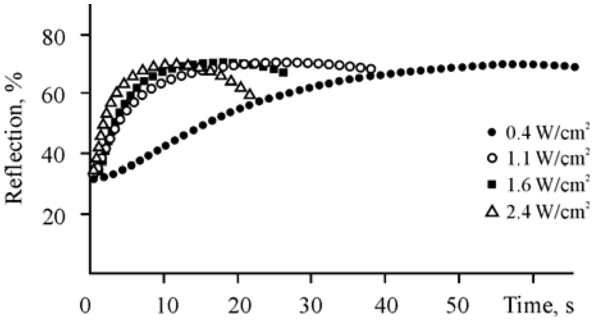

Fig. 5. The dependence of reflectivity of As_2S_3-Al system on exposure time for the film with thickness of 2.2 μm with different light intensity.

The holographic grating with period Λ= 0.4 μm was recorded on the sample with layer thickness of 6.8 μm by light at 532 nm with intensity of 0.97 W/cm^2 in every beam. Diffraction efficiency was measured in the second reflected maximum [2]. As it turned out, the diffraction efficiency of the recorded grating depends on the initial reflectivity of the system in the point of the recording. Thus, the efficiency in the point with minimal initial reflectivity is 1.5 times higher than the diffraction efficiency of the recording in the point with maximal initial reflectivity (Fig. 6). With an average value of reflectivity the diffraction efficiency of the grating is the same as with a minimal one.

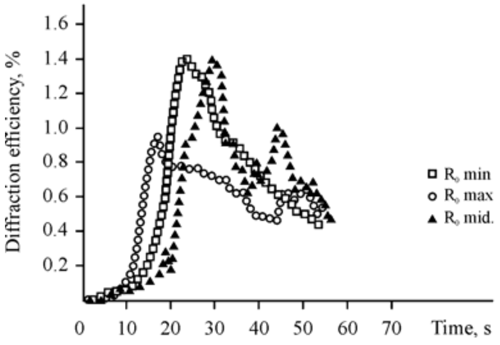

Fig. 6. The dependence of diffraction efficiency of As_2S_3-Al system on exposure time for the film with thickness of 6.8 μm with different initial reflectivity of the system.

The recording of the grating in the samples of different thickness also shows that the highest diffraction efficiency can be obtained during the recording in the film with minimal initial reflectivity (Fig. 7). As the figure shows, the gratings recorded on the samples with layer thickness of 2.2 μm and 6.8 μm have the highest diffraction efficiency.

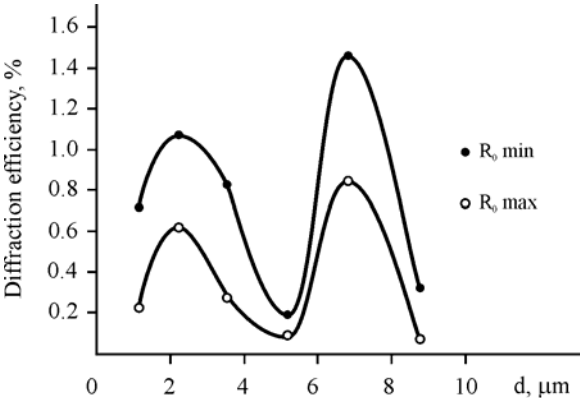

Fig. 7. The dependence of maximum diffraction efficiency of As_2S_3-Al system on As_2S_3 layer thickness with different initial reflectivity of the system.

4. Conclusions

The photoimpact of different intensity on As_2S_3-Al system brings about similar modulations of the reflected signal. For As_2S_3-Al system with As_2S_3 layer thickness of 2.2 μm this modulation was 45%.

As_2S_3 layer thickness influences the modulation of the reflected signal and the sensitivity of the system to laser irradiation. The maximal modulation of the reflected signal – 45% - was achieved in the system with film thickness of 2.2 – 3.5 μm, at the same time photosensitivity was always maximum – 0.08 cm^2/J.

The recording of the holographic grating was performed in As_2S_3-Al system. Its diffraction efficiency depends on both film thickness and initial conditions of reflectivity in the system. Maximal diffraction efficiency 1.2% and 1.5% in the second maximum of reflectivity was achieved for film thickness of 2.2 μm and 6.8 μm respectively, provided the recording was made in the point with minimal initial reflectivity. It is1.5 times higher than diffraction efficiency in the point with maximal initial reflectivity.

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