Section 5. Physics

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INVESTIGATION OF THE HOLOGRAPHIC CHARACTERISTICS OF CHALCOGENIDE GLASSY AS-SE SEMICONDUCTOR FILMS

Abstract. The possibility of using chalcogenide glassy semiconductor films (CSS) for recording and storing holographic information is considered. The dependences of the diffraction efficiency (η), the shift of the optical absorption edge (Δλ) of the films on the prehistory of the initial material and on the composite components of the film are shown.

Keywords: Chalcogenide glassy semiconductors (CGS), diffraction efficiency, arsenic selenide As-Se, hologram, sample transparency coefficient.

Introduction

The development of modern science and technology, which requires a significant increase in the volume of recording, storage and processing of information, necessitates the development and improvement of recording methods based on the use of various information carriers.

Currently, one of the effective ways to solve the problem of reliable, long-term storage of information with a high information density of media is the use of a holographic method of information storage. In recent years, a complex of theoretical and experimental studies has been carried out all over the world to develop holographic storage devices with ultra-high information capacity. Holographic methods make it possible to record, store and restore information presented in the form of pictures, wave fields, spatial images, etc. They show that chalcogenic glassy semiconductors (CGS) containing one or more chalcogens (S, Se, Te) are promising recording materials [1]. The development of semiconductor physics and the widespread use of complex solid-state materials in microelectronics products, in information storage and processing systems, and in various objects puts forward the study of the nature of processes in these materials [2; 3]. For this purpose, we studied the holographic characteristics of CGS films.

Experimental technique.

To determine the diffraction efficiency of holograms recorded on As-Se samples, a holographic setup was used, the scheme of which is shown in Fig. 1.

The entire scheme is placed on the working plate of the UIG-2M factory experimental setup. Holographic recording was made according to the standard two-beam scheme. Convergence angle ≅ 30°. To eliminate vibrations of the optical scheme, all elements are fixed on the surface of the working plate, which is suspended according to the pendulum principle. For recording and reading information, a helium-neon laser He-Ne LG-38 ($\lambda = 632.8$ nm) was used.

The diffraction efficiency was estimated from the ratio of the radiation power of the reference beam, diffracted in the 1st order during the reconstruction of holograms, to the radiation power of the reference beam itself.

We have developed a technique for studying the optical and holographic properties of materials of the As-Se system in the form of thin films deposited by thermal evaporation in a vacuum (10^{-5} Torr) on unheated substrates. The investigated films of As_xSe_{1-x} systems had a thickness of 0.3–4.5 µ. The concentration of As and Se varied from 40 to 60 atomic percent and from 28 to 72 atomic percent, respectively.

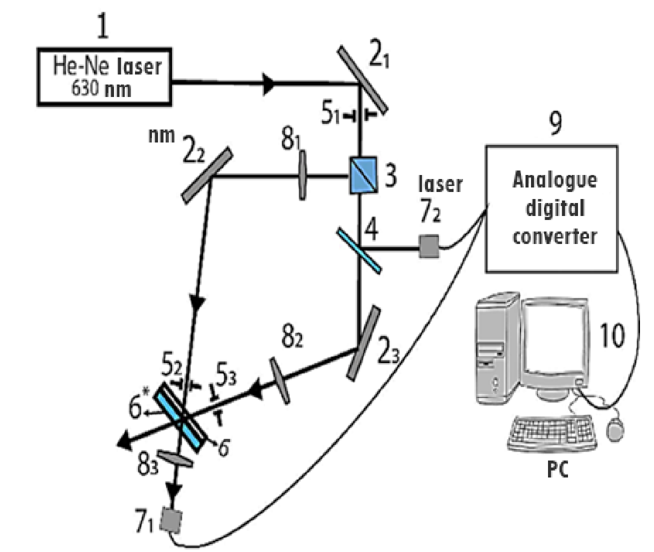

Figure 1. Experimental scheme for studying the holographic characteristics of CGS films. 1 – LG-38 laser; 2_1, 2_2, 2_3 – flat mirrors; 3-cubic prism; 4 – translucent plate; 5_1, 5_2 – aperture masks; 6 – sample, 6* substrate; 7_1, 7_2 – recording devices; 8_1, 8_2, 8_3 – shutters

The choice of the most suitable material for recording information with a laser beam of one type or another was determined by the spectral transmission characteristic of the resulting film. To fulfill this, a number of conditions are necessary: firstly, the condition of uniform absorption of the recording radiation to ensure efficient recording of holograms in the entire volume, and secondly, the condition of low absorption to obtain the highest diffraction efficiency. The fulfillment of these conditions in our case is realized by choosing the operating point in the region of the intrinsic absorption edge. Illumination of samples with helium-neon laser light in most cases was carried out in the region of the absorption edge, at large values of the absorption coefficient [4].

The transmittance of the initial samples and substrates was measured before recording the holograms using a probe beam that was attenuated by a light filter by a factor of twenty.

Results and its discussion

The installation worked in 3 modes:

1. Hologram recording mode; gates 8_1 and 8_2 are open, gate 8_3 is closed. 7_2 – the intensity of the recording beams is recorded.

2. Diffraction efficiency measurement mode (η); Gate 8_1 is closed, gates 8_2 and 8_3 are open. 7_2 registers the intensity of the reference beam, 7_1 registers the intensity of the diffracted beam.

3. Mode for measuring the transparency coefficient of the sample (T); Gates 8_1 and 8_3 are open, gate 8_2 is closed. 7_1 – registers the intensity of the incident, 7_2 – the intensity of the transmitted beam. The accuracy of determining the intensity of the diffracted beam was 1.6%. The size of the hologram was determined by the mask and was equal to ~1.5 mm.

The photo sensors and associated recording devices (7_1, 7_2) are used to measure the diffraction efficiency η, the sample transparency coefficient T, and the energy characteristics of the recording. They are calibrated taking into account the diaphragming effect of the masks (5_1, 5_2, 5_3).

To study the reversibility and erasure of the recorded holograms, a thermostatic furnace with glasses transparent to light was used.

The determined relative values of the diffraction efficiency η and the shift of the optical transmission edge Δλ in the 1st recording cycle are shown in Fig. 2. The scatter of their values is obviously due to some inhomogeneity of the film thicknesses. The maximum transmission was observed in films obtained from a sample with T_{sample}~500 °C.

It should be noted that complete erasure of the prehistory does not occur even after film annealing at the erasure temperature (T_{eras}). As a result, the magnitude of the reverse optical shift of the absorption edge after several "write-erase" cycles for all samples took the same value. As for the diffraction efficiency (η), it should be noted that the observed dependences of it on the thickness of the samples are approximately the same for all processing temperatures, i.e., backstories of the source material. However, the absolute values of η are different. They grow with increasing T, reaching a maximum value at T~500 °C (Figure 2).

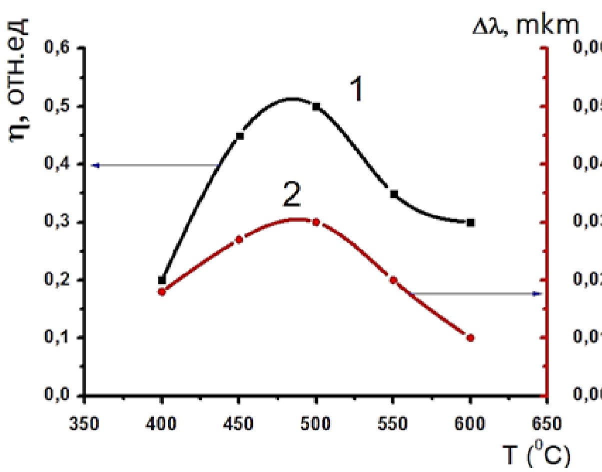

Figure 2. Change in diffraction efficiency (η) and shift of the optical absorption edge (Δλ) of films obtained from bulk materials with different prehistory

The spectral dependence of the optical transmission of freshly deposited, annealed films in the region of the fundamental absorption edge (0.4–1.0 μm) was studied on a Shumadzu spectrophotometer. On the curves of dependences of Δλ and η on T_{sample} (see Fig. 2), a maximum is noted in the region of ~ 500 °C. It is difficult to analyze the mechanism of the effect of structural features of bulk samples on the characteristics of photoinduced transformations in films in detail [5; 6; 7]. However, it is important to emphasize the presence of such a dependence and a significant, more than 2-fold, change in the diffraction efficiency with a change in the thermal history of the source material.

The compositional dependences of the diffraction efficiency and the shift of the optical absorption edge for films of the As-Se system (Fig. 3.) have a maximum for films with an arsenic content of ~ 65 at%. The decrease in the diffraction efficiency with an increase in the As content above 65 at% is obviously due to the instability of the films, the composition of which goes beyond the limits of their glass transition region. An increase in the diffraction efficiency with a change in the arsenic concentration from 40 to 65 at% is probably due to reasons similar to those considered for three arsenic selenides with different thermal prehistory [8].

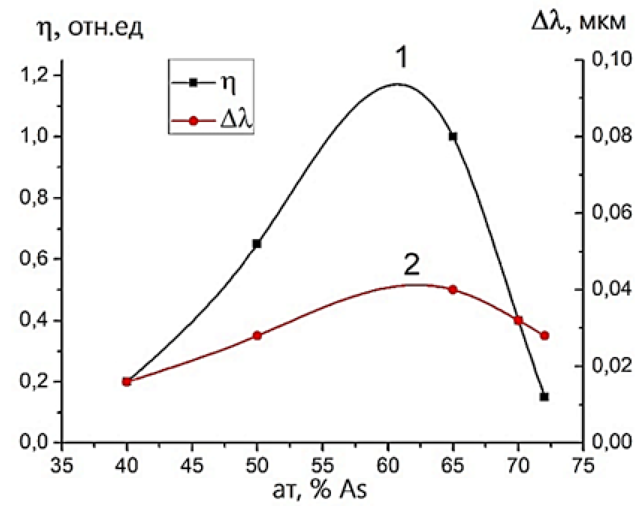

Figure 3. Compositional dependences of the diffraction efficiency (1) and the shift of the optical absorption edge (2) in As-Se films

Conclusions

It has been established that the dependences of the values of the diffraction efficiency of holograms and the shift of the optical absorption edge of As-Se films on the processing temperature of the initial material have an extreme character with a maximum value at $T_{sample} \approx 500$ °C. It should be noted a significant, more than 2-fold change in the diffraction efficiency with a change in the thermal history of the source material.

The experimental results obtained testify in favor of a significant influence of the prehistory and volume content of chalcogens introduced into arsenic on the absolute values of the optical-holographic parameters of the materials under study.

The possibility of using such glassy chalcogenide semiconductors (As-Se films) as promising materials in optical processing and information storage systems is shown.

References:

1. Азаматов А. З. Т., Утамурадова Ш. Б., Базарбаев Н. Н., Бекчанова М. Р., Азаматов Т. З., Бахромов А. Б. Голографические свойства халькогенидных стеклообразных полупроводниковых пленок // Прикладная физика,– № 2. 2022.– С. 39–45.
2. Акаев А. А., Гуревич С. Б., Жумалиев К. М. Голографические системы хранения и выборки информации // Илим.– Бишкек; СПб., 2000.– 408 с.
3. Джаманкызов Н. К., Пецкус А. М., Гуревич С. Б., Жумалиев К. М. Влияние процессов записи на информационные характеристики записываемых голограмм // – Москва Диалогмифи. 2004.– 11 с.
4. Tanaka K. Have we understood the optical absorption edge in chalcogenide glasses // Journal of Non-Crystalline Solids.– No. 431. 2016.– C. 21–24.
5. Электронные явления в халькогенидных стеклообразных полупроводниках // под ред. К. Д. Цендина.– СПб.: Наука, 1996.– 486 с.
6. Lyubin V., Klebanov M., Shapiro L., Lisiansky M., Spektor B., Shamir J. Peculiarities of Photorefraction Effect in thick Glassy As_2S_3 Films // J. of Optoelectr. and Adv. Mater.– V. 1.– No. 3. 1999.– P. 31–35.
7. Anisimova N. I., Bordovsky G. A., Bordovsky V. A., Castro R. A. The Photoinduced Change of Dissolution Rate in As_2Se_3 Glasses // Radiation Effects and Defects in Solids.– V. 156.– No. 4. 2000.– P. 365–369.
8. Азаматов З. Т., Минаев В. С., Михалев Н. И. Влияния тепловой предыстории и состава на фотостимулированные превращения в пленках системы As-Se: // сб. «Аморфные и стеклообразные полупроводники в пленках системы As-Se».– Калининград, 1982.