INVESTIGATION OF REGISTRATION OF THE OPTICAL INFORMATION IN THE AMORPHOUS As-Se THIN FILMS

M.S.Iovu, V.G.Ciorba, E.P.Colomeico, A.M.Nastas, A.M.Prisacar

Center of Optoelectronics, Institute of Applied Physics, Academy of Sciences of Moldova,

Str. Academiei 1, MD-2028 Chisinau, R.Moldova

Abstract: The effect of light-induced photodarkening in amorphous $As_{100-x}Se_x$ ($x=40\div98$) thin films for different thickness and film composition was investigated. It was established a strong dependence of the red shift of the absorption edge and refractive index under light irradiation on the film composition and thermal treatment. It was established that the more sensitive films to photodarkening and holographic recording correspond to non-stoichiometric compositions of $As_{55}Se_{45}$ and $As_{60}Se_{40}$ glasses. The experimental results are interpreted in terms of structural optical polymerization process, which includes the transformation of As_4Se_4 and Se_2 structural units in homogenius $AsSe_{3/2}$ network.

1. INTRODUCTION

The considerable changes of the optical absorption and of the refractive index of amorphous material associated with photostructural transformations under the light exposure have been stimulated the application of arsenic chalcogenides as optical and holographic recording media, inorganic photoresists, as passive elements of integrated optics, and imaging devices [1]. The increasing of the absorption is caused by the shift of the absorption edge to lower photon energies, and is belived to be due to broadening of the valence band, the top of which is formed mainly by states of lone-pare electrons of the chalcogen atom. Because the composition of chalcogenide glass determines the structural units and the mean coordination number of the amorphous solids [2], the effect of the composition in the glassy system $As_{100-x}Se_x$ ($x=40\div98$) on the degree of photostructural transformations has been studied. In the last years many investigations has been done on photodarkening process in amorphous chalcogenides, but still now does not exist a unique model for its explanation. Recently some results on photodarkening in amorphous $As_{40}Se_{60}$ were interpreted in frame of the "slip motion" model [3], were obtained some experimental results concerning the thickness dependence of photodarkening in α-$As_{40}Se_{60}$ [4] and α-$As_{40}Se_{60}$ doped with Pr and Dy [5].

A special attention is done to the composition dependence of photodarkening characteristics in the films of the glassy system $As_{100-x}Se_x$ (x=40÷98). It was established, that the higher sensitivity on photodarkening as result of light exposure is characteristic for the non-stoichiometry $As_{60}Se_{40}$ amorphous films, and decrease with increasing of Se content in the $As_{100-x}Se_x$ glass. The experimental results are interpreted in terms of structural optical polymerization process, which includes the transformation of As_4Se_4 and Se_2 structural units in homogeneous $AsSe_{3/2}$ network [6,7].

2. EXPERIMENTAL

The glasses $As_{100-x}Se_x$ (x=40÷98) were synthesized from the elements of 6N (As, Se) purity by conventional melting technique. The $As_{100-x}Se_x$ thin films of different thickness 0.27 to 4.5 μm were prepared by "flash" thermal evaporation in vacuum onto glass substrates held at T_{subs}=100 °C. For optical transmission an UV/VIS Specord (in the 0.3-0.8 μm spectrum range) CARLZEISS Jena production was used.

To initiate photostructural transformations in thin film samples a He-Ne laser (λ=0.63 μm, W=10 mW) was used as a source of light exposure. The splitter was used for divide the laser beam: one Si-photodetector was used for measuring the film transmittance, and another Si-photodetector was used for measuring the time stability of the laser intensity. The total transmittance of the film was currently measured during the exposure time with the aid of a registration module. The experimental set-up included a laser, a digital build-in PC-card for data acquisition PCI-1713A connected with the Si-photodetector. Special software was elaborated for automatic measurements.

The microholograms on the amorphous As-Se films were registered by means of the interference of two He-Ne laser beams (λ=6328 nm) with a power of W=30 mW. The kinetics of diffraction efficiency growth was measured by registration of the intensity of the 1-st interference maximum versus time exposure.

3. RESULTS

3.1. OPTICAL TRANSMISSION

The films based on arsenic chalcogenides usually become darkened due to photo-structural transformations under action of light from the region of fundamental optical absorption (so called photodarkening). Fig. 1a shows the transmission spectra of amorphous $As_{60}Se_{40}$ thin films, before (curve 1) and after exposure (curve 2) during 1 hour. The enhancement of the absorption is caused by the shift of the absorption edge to lower photon energies. The photoinduced shift of the absorption edge $(\Delta\lambda)$ after exposure decrease the transmission at a fixed wavelength and increase the refractive index n of the amorphous material. The photoinduced shift of the absorption edge $(\Delta\lambda)$ as well as the changes in the refractive index (Δn) depends at the fixed temperature depends on

the exposure intensity, exposure time, film thickness, and on the composition of the amorphous thin film. The maximum shift of the absorption edge $\Delta\lambda$ at the level of transmittance T=20 % consists $\Delta\lambda$=920 nm, for $As_{60}Se_{40}$ films, while for $As_{10}Se_{90}$ and As_5Se_{95} films this value is only $\Delta\lambda$=2÷5 nm (Fig.2b). In the same matter, the relative change of the refractive index $\Delta n/n$ is bigger for $As_{60}Se_{40}$ films ($\Delta n/n$=0.394) and decrease with increasing the concentration of Se in $As_{100-x}Se_x$ glassz system. Our experimental data correlate with the experimental data for As-Se films obtained in [8].

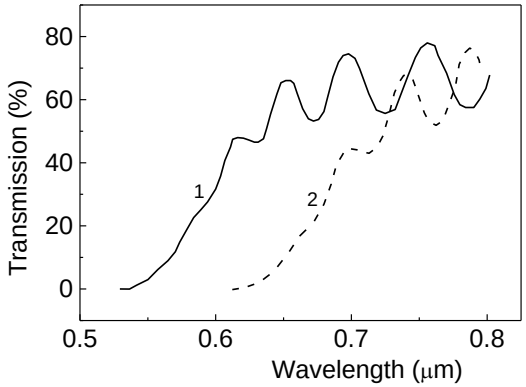

Fig.1a. The transmission spectra of amorphous $As_{60}Se_{40}$ thin films *L=1.3 μm*, before (1) and after exposure (2).

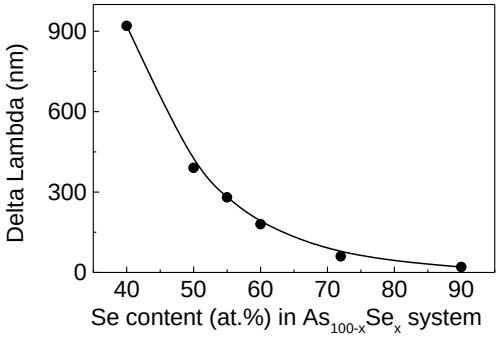

Fig.1b. The dependence of the photoinduced shifts of the absorption edge *(Δλ)* versus Se content (at. %) in $As_{100-x}Se_x$ glass system.

3.2. HOLOGRAPHIC RECORDING PROCESS

Fig.3a shows the kinetics of growth of the diffraction efficiency for amorphous $As_{50}Se_{50}$ and $As_{60}Se_{40}$ thin films during exposure as result of interference of two He-Ne laser beams (λ=6328 nm) with a power of *W*=24 mW. The intensity of the first interference maximum was recorded in the transmittance mode. The maximum of the diffraction efficiency is reached at 10-15 min of the exposure and after that for the compositions richer in Se the saturation take place.

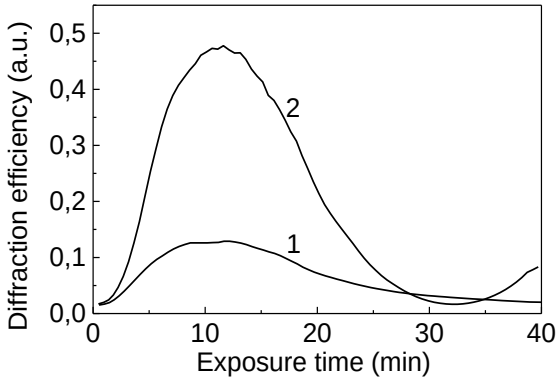

Fig.3a. The kinetics of growth of the diffraction efficiency versus exposure time for amorphous $As_{50}Se_{50}$ (curve 1, *L=1.3 μm*) and $As_{60}Se_{40}$ (curve 2, *L=1.3 μm*) thin films.

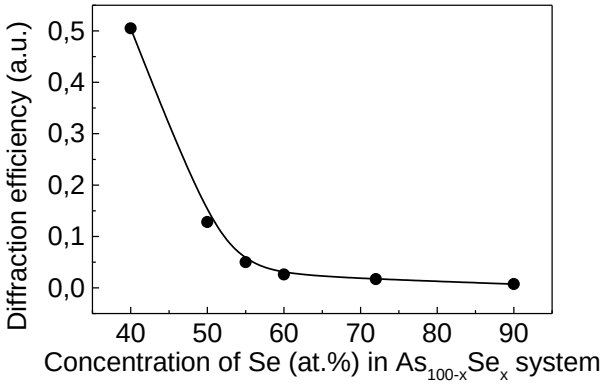

Fig.3b. The dependence of the diffraction efficiency versus Se concentration in the $As_{100-x}Se_x$ glassy system.

For the compositions richer in As the kinetics of the diffraction efficiency represents a curve with maximum or a sinusoidal. The deletion process of the optical information due to the time exposure may cause the fall dawn of the diffraction efficiency after the maximum.

The holographic sensitivity of the amorphous films and the diffraction efficiency of the hologram has, decreases with increasing of the selenium content in $As_{100-x}Se_x$ glassy system (Fig. 3b). These dependences are in a good agreement with earlier obtained experimental data [8].

4. SUMMARY

The composition dependence of the transmission spectra, photodarkening characteristics, and kinetics of recording process of holographic information in the films of the glassy system $As_{100-x}Se_x$ (x=40÷98) was investigated. It was established, that the higher sensitivity to light exposure exhibit the non-stoichiometric $As_{50}Se_{50}$, $As_{55}Se_{45}$, and $As_{60}Se_{40}$ amorphous films, and decrease with increasing of Se content in the $As_{100-x}Se_x$ glass. The experimental results are interpreted in terms of structural optical polymerization process, which includes the transformation of As_4Se_4 and Se_2 structural units in homogenius $AsSe_{3/2}$ network [6,7].

REFERENCES

[1]. Optoelectronic Materials and Devices. Vol.1, 2004. Non-Crystalline Materials for Optoelectronics. Eds. G.Lucovsky & M.Popescu, INOE, Bucharest, 2004.

[2]. Georgiev D.G., Boolchand P., Micoulaut M., Phys.Rev. **B62**, R9228 (2000).

[3]. Shimakawa K., Yoshida N., Ganjoo A., Kuzukawa Y., Singh J., Phil.Mag.Letters, 77, 153 (1998).

[4]. Hayashi K., Mitsuishi N., J. of Non-Cryst. Solids **299 &302**, 949 (2002).

[5]. Iovu M.S., Shutov S.D., Boolchand P., Colomeico E.P., Ciorba V.G., Iovu M.S., Popescu M., J. of Optoel. and Adv. Materials **4**, 857 (2002).

[6]. Frumar M., Firth A.F., Owen A.E., J. of Non-Cryst. Solids **59&60**, 921 (1983).

[7]. Shpotyuk O.I., Opto-Electronics Review **11**, 19 (2003).

[8]. Lyubin V.M., Photographical process on the base of Vitreous Chalcogenide glasses. In the Book: NON-SILVER PHOTOGRAPHICAL PROCESSES, Edited by A.L.Kartujanskii, Chimia, Leningrad, pp. 193-215, 1984 (in Russian).