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INFLUENCE OF CORONA DISCHARGE ON PHOTOINDUCED MODIFICATION OF OPTICAL CHARACTERISTIC OF Cu–As_2Se_3 THIN FILM STRUCTURES

A. NASTAS*, O. IASENIUC, M. IOVU
Institute of Applied Physics, 5 Academiei Str., Chisinau, MD-2028, Republic of Moldova

The object of our current investigation is Cu-As_2Se_3 thin film structures. The impact of corona discharge on photoinduced modifications of the transmission spectra of both as-deposited and exposured with actinic light of the Cu-As_2Se_3 structures have been studied. Two cases have been investigated. First normal irradiation of the film structures without charging, and another one, when exposure was switched on, 7 kV corona charge at different polarity was applied. As a result, in the region of the weak absorption in the transmission spectra the photobleaching effect was observed and in the region of the strong absorption the photodarkening phenomena was manifested. In the region o weak absorption higher values of photobleaching was observed during exposure in the field of positive corona discharge. The obtained results are qualitatively analyzed taking into account the photodarkening of the semiconductor during it doping with Cu ions as well as transmission increases of the structure during photodiffusion of the cupper in the amorphous semiconductor.

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Keywords: Thin film structures, Transmittance spectra, Corona discharge, Photodarkening and Photobleaching phenomena, Photoinduced modifications

1. Introduction

Thin film structures based on chalcogenide glass semiconductors (ChGS) hold a special place among the optical registration media for recording holographic images. It is due to their capability to have a surface relief through etching in chemical solutions as well as high resolution, about nanometers [1].

The main disadvantage of such registration media is a relatively low photosensitivity about ~ 10-10^2 cm^2/J [1]. In [2, 3] the authors have tried to rise photosensitivity of the metal-ChG structures by applying of corona charge to ChG thin layers during their light exposure. It was established [3], that application of negative corona discharge during recording of optical holographic diffraction gratings in Cu-As_2Se_3 thin film structures, in comparison of positive corona discharge, increases the holographic sensibility, the diffraction efficiency and the depth of the chemical etched relief. However, the photoinduced modifications of transmission spectra of such structures in field of corona discharge and without haven't been studied in those investigations.

The main aim of this work was to investigate the impact of corona discharge on photoinduced modification of the transmission spectra in the Cu-As_2Se_3 structure.

2. Experimental

The bulk As_2Se_3 chalcogenide glasses were prepared from the elements (As, Se) of 99.99% purity by conventional melt quenching method. Thin films of Cu and As_2Se_3 were sequentially deposited by the vacuum thermal evaporation ($p=3{,}7\times10^{-3}$ Pa) from the Mo boats onto unheated glass substrates. The deposition rate of chalcogenide films was about 5 nm/s. The

* Corresponding author: nastas_am@rambler.ru

thickness of the metal Cu layer that serves as an electrode for the recording in the presence of the corona discharge was 40 nm. The transparence of Cu layer of such thickness was about 27% measured at λ = 0.633 μm. Thicknesses of As_2Se_3 layers were d = 0.27 μm and d = 0.11 μm. Such layer thicknesses of As_2Se_3 were also used in [3].

The transmission spectra studying of the Cu-As_2Se_3 structure was performed before and after uniform irradiation using He-Ne laser (λ=0.6328 μm, exposure energy H=0.5 J/cm^2), both with applying of the electric field of corona discharge (± 7 κV) and without. Note that the samples are exposed from the ChGS side. The corona setup (Fig.1) consist from high voltage box and the corona electrode which is a thin wolfram wire (about 60 μm), and the voltage +7 κV or -7 κV was applied across it. The distance between sample surface and wolfram wire was 17 mm. The optical transmission spectra of the samples were always measured using a Specord UV–VIS spectrophotometer, before the optical recording procedure.

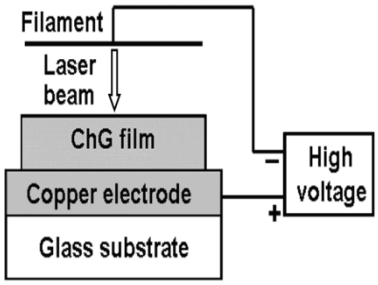

Fig. 1. Diagram of corona discharge setup.

2. Results and discussion

Fig. 2 represents the transmission spectra of as-deposited metal-As_2Se_3 structures before and after light exposure without applying the field of corona discharge. Curves 1 and 3 are for film thickness 0.11 μm and curves 2 and 4 are for film thickness 0.27 μm, respectively. As can be seen from Fig. 2, in the region of weak absorption in the transmission spectra of the investigated structures was observed photobleaching that is caused by reducing in the thickness of the copper layer. Maximums on the curves (films with thickness 0.27 μm) appeared because of the light interference phenomena in thin films.

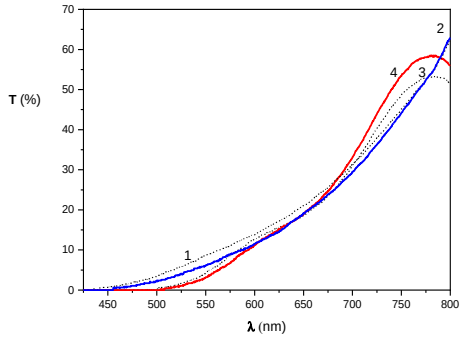

Fig. 2. Transmission spectra of the metal-As_2Se_3 structures before (curves 1, 3) and after (curves 2, 4) light exposure.

A family of curves ΔT(λ) = T(λ) -T_0(λ) for As_2Se_3 layer with thicknesses d = 0.27 μm and d = 0.11 μm are sown in Figures 3 and 4. Here T_0(λ) and T(λ) are transmission of the studied structure, before and after light exposure, respectively. In every figures curve 2 corresponds to an exposured sample with visible light without applying the corona discharge, and curve 1

corresponds to the case when a negative electrical field is applied. And curve 3 corresponds to the case when a positive electrical field is applied.

Fig. 3 suggests that in the region of the short wavelength spectrum the curves 1-3 practically coincide. This means that the applied electrical field don't impact on photodarkening phenomena in the Cu- As_2Se_3 structure, nevertheless affect the photodiffusion rate of the copper ions in As_2Se_3 film. Moreover, corona discharge has an essential effect on photobleaching of the Cu-As_2Se_3 structure, observed in the long wavelength spectrum. That is, the positive corona discharge increases photobleaching (you can compare curves 3 and 2 from fig. 3), but the negative corona discharge vice versa weaken it (you can compare curves 1 and 2 from fig. 3).

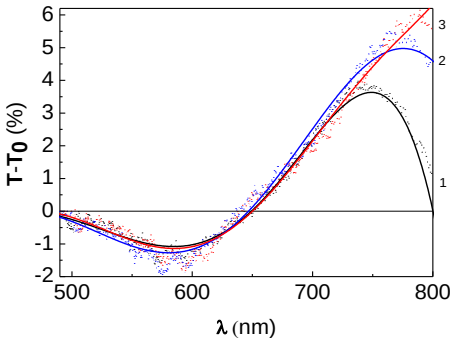

Fig. 3 Increment modification of the transmission spectra of Cu-As_2Se_3 structure (L_{ChG} = 0.27 μm) for different values of the electrical field of corona discharge U: - 7 kV (1), 0 kV (2) and + 7 kV (3).

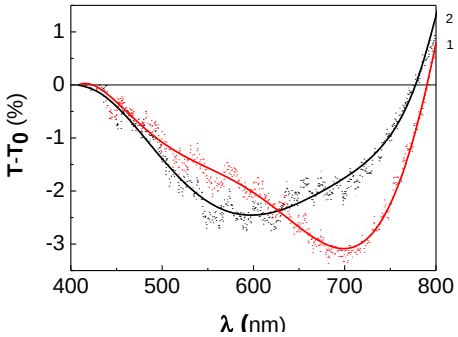

Fig. 4 Increment modification of the transmission spectra of Cu-As_2Se_3 structure (L_{ChG} = 0.11 μm). Curve 1 - exposure in the field of corona discharge (U: - 7 kV) and curve 2 - exposure without corona discharge.

The weakening of the photobleaching of Cu-As_2Se_3 structure under light exposure during applying the negative corona discharge was also observed in the case of the layer thickness L_{ChG} = 0.11 μm (Fig. 4). The difference of the Cu-As_2Se_3 structure with the thickness 0.11 μm is that when it is irradiated in the field of negative corona discharge, the position of the minimum (that is correspond of the maximum photodarkening) noticeably shifts toward longer wavelengths in comparison with the case without corona discharge.

The obtained results qualitatively can be explained taking into consideration the following facts. It is known that the doping of the chalcogenide film with silver ions leads to their darkening in the shot wavelength region of the spectrum [4]. It is considered that the Cu ions photodiffusion into As_2Se_3 underlayer results it shifting of the absorbtion edge towards long wavelength region which means darkening of the Cu-As_2Se_3 structure. On the other hand, the photodiffusion Cu ions from electrode leads to decreasing of it thickness that causes decreases absorption at all in the Cu-As_2Se_3 structure. Thus, the combination of a photoinduced increase in the light absorption in the

As_2Se_3 layer and a decrease in the light absorption in the metal layer leads to a minimum on the spectral dependence of the photoinduced transmission modifications $\Delta T(\lambda)$.

It was found that field of corona discharge impact on photodiffusion process of Cu ions into As_2Se_3 film. The electrical field appeared in the Cu-As_2Se_3 structure after applying of the negative voltage of corona discharge during light exposure enhances the photodiffusion of the Cu ions, which was at the same time positively charged, while at positive voltage of corona discharge the electric field manifests as a braking electric field and photodiffusion was weakened. Attenuation of the photobleaching effect, when is applied a negative corona discharge in comparison with normal irradiation (compare curves 1 and 2 in Fig. 3) can be explained by the fact that the rise of the light absorption in the doped As_2Se_3 sublayer is stronger than the transmission in the copper layer.

Taking into consideration the experimental results obtained in this work, it can be concluded that the influence of the field corona discharge applied during irradiation to the Cu-As_2Se_3 structure on its optical properties is manifested mainly in the modifications of the transmission of the As_2Se_3 layer. Essential light absorbance in the short wavelength region is observed for non-doped As_2Se_3 layer. In this case, the effect of the corona discharge on the total transmission of doped and non-doped As_2Se_3 sublayer is weaker than in the long-wavelength region.

Finally, note that the investigation of the spectra of photoinduced changes of the transmission $\Delta T(\lambda)$ allow us to understand it contribution in absolute value of the diffraction efficiency of phase-amplitude holographic diffraction gratings recorded in Cu- As_2Se_3 layers.

4. Conclusions

Exposure of the Cu- As_2Se_3 structure with actinic light changes its transmission spectrum. The photodarkening phenomenon is observed in short wavelength region while in the long wavelength region the photobleaching effect is manifested.

When is applied the negative corona discharge the weakness photobleshing was observed. The ratio of achieved values of the maxima in the expositional dependences of the diffraction efficiency of the holographic gratings using simultaneously during recording the corona discharge of different polarity are in accordance with the respective photoinduced changes of the transmission.

Acknowledgments

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