# Photo-thermo-plastic media based on chalcogenide glassy semiconductors for real-time holography

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The possibility of photo-thermoplastic carriers sensitivity increase by an additional light up during recording process was studied. The investigations of microelectronic microobjects hologram recording on photo-thermoplastic carriers were carried out.

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## 1. Introduction

The photothermoplastic (PTP) carriers have high value of holographic sensitivity, resolution power and short time of hologram recording [1-4]. There are well known PTP carriers based on organic [1] and inorganic [2-4] photosensitive semiconductors, which do not differ by recording principle but only by main holographic parameters. For PTP carriers based on chalcogenide glassy semiconductors resolution power of 4000 $mm^{-1}$ [3] and holographic sensitivity of about $6\cdot10^6$ $cm^2/J$ [4] were demonstrated. The potential of the use of PTP carriers in holographic microscopy [2], real-time interferometry [3] and in the impulse hologram recording in nanosecond range [4] were also explored.

The objective of the present work is the investigation of the processes of micro-objects hologram recording at low light intensity conditions.

## 2. Experimental setup

For PTP carriers' fabrication the complex vacuum technology was used. A flexible light-penetrable polyetilentereftalat chrome metallized film (1, Figure 1) was obtained through method of electron-beam evaporation in vacuum. The photo-semiconductor layer (3) of varying thickness is based on chalcogenide glassy semiconductor (CGS) of the As-Se-S-Sn system and has been obtained by thermal deposition in vacuum. The thermoplastic layer of poly-N-epoxypropylcarbazole (4) with a thickness of 0.55 μm was deposited on the semiconductor layer by cuvette-meniscus method of irrigation from solution of thermoplastic polymer in toluene. The recording process may be briefly described as follows. The PTP-carrier was placed in the specialized programmable PTP recording device, which provides uniform heating of the PTP carrier to a viscous state of the thermo-plastic layer. Simultaneously with the start of the light exposure the high-voltage charger is switching on and thermoplastic surface is charged with positive charge of ionized air. At the same time on the light exposed area of the CGS, the opposite charge is induced, due to the effect of electro-static interaction and a phase relief image is formed on the surface of the thermoplastic layer [1-5].

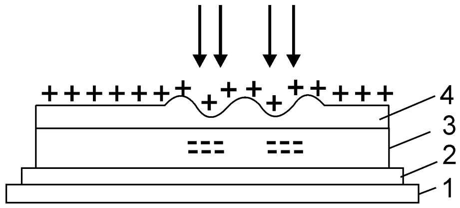



*Fig. 1. Schematic demonstration of a photo-thermoplastic carrier: 1) flexible film, 2) transparent metal electrode, 3) photo-semiconductor,4) thermoplastic.*

The FTP carriers were designed for holographic recording at the light wavelength λ = 532 nm. Spectral sensitivity of FTP carriers depends on the composition of the CGS layer [2-5]. Thus, we have fabricated films of CGS system $As_2S_3$-78 mol.%, $As_2Se_3$-22 mol.% with thicknesses in the range of 0.2 – 2.6 μm and investigated their spectral photoconductivity. The spectral dependence of the photocurrent (in amperes) on the incident power of irradiation (in watts, curve 1, Figure 2,) shows maximum photosensitivity of CGS near λ = 530 nm.

Relief –phase diffraction gratings were recorded by the use of an optical system based on DPSS laser operating at λ = 532 nm wavelength. The PTP carrier was illuminated by equal intensity plane-parallel laser beams, which were forming in the photosensitive semiconductor layer an interference grating with spatial frequency ν = 1000 $mm^{-1}$. Diffraction gratings were recorded with total intensity of laser beams $I = 1.2\cdot10^{-7}$ $W/cm^2$ and the time of irradiation t = 1.4 s what corresponds to the power exposure $H = 1.68\cdot10^{-7}$ $J/cm^2$. The diffraction efficiency (DE) of recorded diffraction grating was 1% (defined as the ratio of light intensity in the first diffraction maximum to the light intensity passing through the unexposed area of the PTP carrier). This method of DE determination allows excluding the influence of light absorption in the metallic electrode – semiconductor structure. Holographic sensitivity was defined as the value of the exposure when the diffraction efficiency of the hologram achieved 1%. Thus, for our PTP carriers, the holographic sensitivity was $S = 6\cdot10^{6}$ cm$^2$/J for λ = 532 nm.

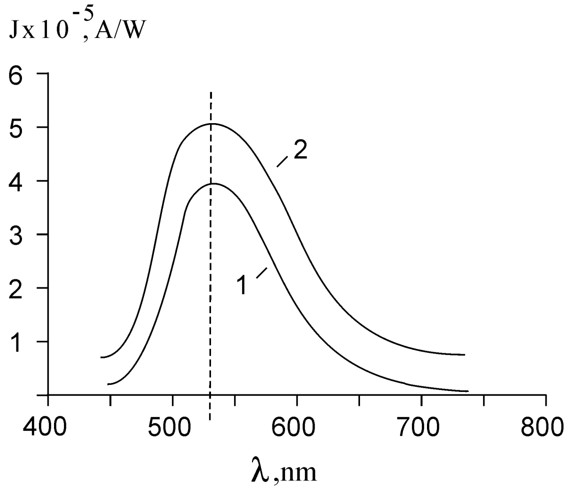



*Fig. 2. The spectral dependence of the photoconductivity: 1) without additional illumination, 2) with additional illumination by λ = 633 nm.*

The study of holographic recording on the obtained PTP carriers of micro-objects and determination of their dimensions were carried out. The optical scheme of the unit for hologram recording is shown in Fig. 3.

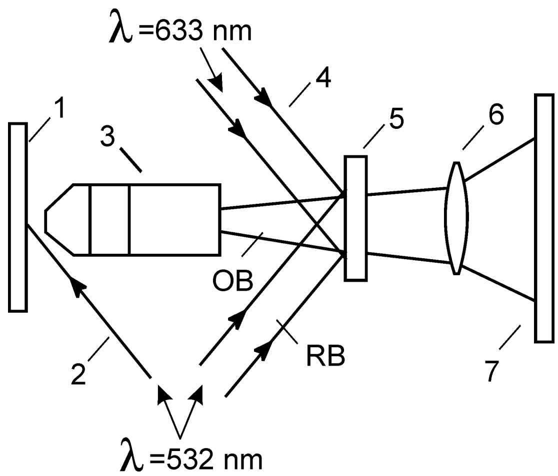
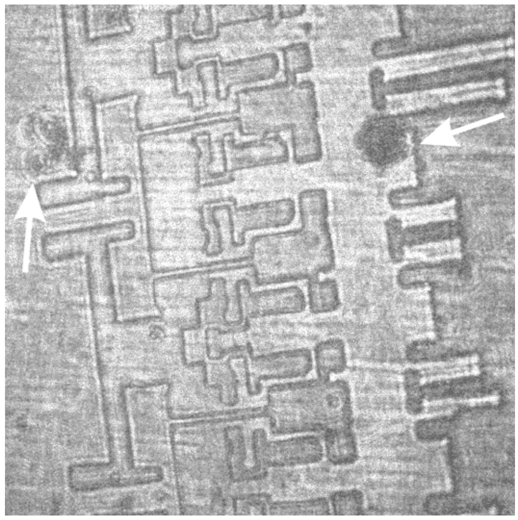



*Fig. 3. Schematic presentation of the holographic setup: 1) object, 2) laser beam λ = 532 nm, 3) microscope, 4) laser beam λ = 633 nm, 5) PTP carrier, 6) lens, 7) screen.*

A single-crystal silicon plate with photolithography deposited integrated circuit elements was used as an object (1, Fig. 3) for the hologram recording. The silicon plate was illuminated by the laser beam 2 (with λ = 532 nm) and the zoomed (by the microscope 3) image of the object (object beam OB) was projected on the PTP carrier 5). The hologram was recorded as a result of interference of diverging object (OB) and reference (RB) beams. By illumination of the recorded hologram with the RB, the reconstructed image of the initial object was observed on the screen 7. The exposure of PTP carrier for hologram recording was the same as for diffraction grating recording ($H = 1.68\cdot10^{-7}$ J/cm$^2$). This exposure was enough to record the hologram with DE ~ 1%. The reconstructed image of the hologram is shown in Fig. 4a.



a)



b)

*Fig. 4. Reconstructed images of holograms: a) without additional illumination, b) with additional illumination.*

On the reconstructed image we observe only the parts of the circuit having high reflection. However, the recording of holographic images of real objects with diffraction efficiency of 1% is not enough to obtain a good image of the initial object.

For detecting the effect of increasing the sensitivity of PTP carriers the spectral dependence of photocurrent of CGS with additional illumination was studied. During the measurement of photocurrent's spectral dependence, the semiconductor layer was constantly illuminated by a monochromatic laser radiation $\lambda = 633$ nm with intensity I = $10^{-6}$ W/cm$^2$. Spectral dependence of photocurrent (curve 2, Fig. 2) shows an equal increase in the all wavelength range of measurement. This property of CGS can be used to increase the sensitivity of PTP carriers for hologram recording in laser radiation, $\lambda = 532$ nm using an additional illumination at $\lambda = 633$ nm.

The second hologram of microobject was recorded with additional illumination of PTP carrier with laser radiation $\lambda = 633$ nm (4, Fig. 3). During the hologram recording, synchronized shutters were used to simultaneously switch on (during t = 1.4 s) light of lasers with $\lambda = 532$ nm (OB and RB) beams, and $\lambda = 633$ nm (for additional illumination of PTP carrier). The total exposure of object and reference beams ($\lambda = 532$ nm) was $H_{\lambda=532\ nm} = 1.68\cdot10^{-7}$ J/cm$^2$ and the additional illumination of PTP carriers ($\lambda = 633$ nm) was $H_{\lambda=633\ nm} = 7\cdot10^{-7}$ J/cm$^2$. After recording the hologram was illuminated by the reference beam (RB, Fig. 3). The reconstructed image is shown in Fig. 4b. As we can see from Fig. 4b, the whole image of the initial object was restored. One can also observe photolithography micro-defects (white arrows) which are clearly seen on Fig. 4b.

## 3. Results and discussion

The improvement of the holographic DE thanks to the additional illumination can be explained by peculiarities of photo-thermoplastic recording process. The thermoplastic deformation during the recording process occurs under the influence of Coulomb's interaction between positive charges on the surface and (induced under the action of light) negative charges in the semiconductor layer. The Coulomb's interaction force is directly proportional to the product of charges on the surface and in the photosensitive layer. In the absence of additional light up, the induced charges (under the action of laser with $\lambda = 532$ nm) are not enough for thermoplastic deformation. The PTP carrier illumination with laser radiation with $\lambda = 633$nm is inducing an additional negative charge in the entire volume of photosensitive semiconductor (curve 2, Fig. 2). Thus, in the presence of the uniform light up (with $\lambda = 633$ nm) the interference pattern (in the form of light and dark fringes formed by OB and RB beams) intensity is "shut up". In the illuminated places the negative charge is induced both under the influence of light fringes of the interference pattern, as well as by the additional light up with $\lambda = 633$ nm. However, in the dark places of the interference pattern the charge is induced only under the action of light with $\lambda = 633$ nm and this charge is not enough for thermoplastic deformation. So, a hidden electrostatic contrast in the illuminated and dark segments of PTP carrier will be obtained [2]. At this, the charge in the illuminated places of the interference pattern will be enough for thermoplastic deformation and relief-phase hologram recording.

## 4. Conclusion

Additional illumination of PTP carriers during the recording process by laser radiation with the wavelength, which is different from the hologram recording wavelength, increases holographic sensitivity of PTP carriers. This approach can be successfully applied for hologram recording of objects with low reflection properties. In addition, the suggested method will be useful for the study of some micro-objects, (for example, in microelectronics, biology, medicine), where the influence of high power laser radiation can change their properties or even destroy the object. In such a case, the week reflected laser signal from an object can be compensated by the additional light radiation of PTP carriers

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## References

[1] B. Mailhot-Jensen, A. Rivaton, J. Pilichowski, A. Chirita, E. Chilat, G. Dragalina, International Journal of Photoenergy, **2010**, 1 (2010).
[2] A. Chirita, Journal of Modern Optics, **57**, 854 (2010).
[3] A. Chirita, N. Kukhtarev, T. Kukhtareva, O. Korshak, V. Prilepov, I. Jidcov, Journal of Modern Optics, **59**, 1428 (2012).
[4] A. Chirita, F. Dimov, S. Pradhan, P. Bumacod, O. Korshak, Journal of Nanoelectronics and Optoelectronics, **7**, 415 (2012).
[5] A. Chirita, N. Kukhtarev, O. Korshak, V. Prilepov, Iu. Jidcov, Laser Physics. **23**, 036002 (2013).

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