
ITMO UNIVERSITY
CHARACTERISTICS OF NRC "KURCHATOV INSTITUTE" MATERIALS FOR COLOR HOLOGRAPHIC RECORDING
N.D.Vorzobova*, R.V.Ryabova**
*Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics, Russian Federation, 197101, St. Petersburg, Kronverksky av., 49
** National Research Centre "Kurchatov Institute", Russian Federation, 123182, Moscow, pl.Akademika Kurchatova, 1
vorzobova@mail.ifmo.ru, rose_ryabova@mail.ru

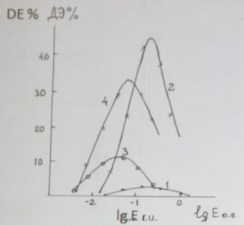
Actuality and direction of research

Despite the intensive development of non-silver materials, including polymeric medium, silver halide materials remain actual. This is due to the advantages in complex of its characteristics, including the light sensitivity, resolution, possible dimensions, the range of applications.

This report presents the results of development and research together with NRC «Kurchatov Institute» of silver halide materials for holographic recording with continuous and pulse laser radiation:

- materials for monochrome pulse recording (transmission holograms)
- materials for colored pulse recording (transmission holograms)
- materials for colored recording using continuous laser radiation (reflection holograms)

Specificity of sensitivity high-resolution silver halide materials to pulse radiation



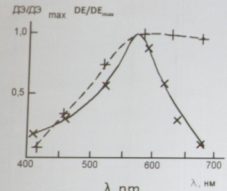
The dependence of the diffraction efficiency on exposure for materials with the size of silver halide nanocrystals 20 (1) and 30 (3)nm.
1,3 - pulse duration of 10 ns
2,4 -continuous radiation

The problem of the using high-resolution materials for pulse recording of reflection holograms of live objects:
- great reciprocity failure
- low sensitivity (not enough for not danger holographic portraits of a man recording)

The concepts - two-stage process:
1 - recording of transmission holograms on materials with large sizes of nanocrystals (40-60 nm);
2 - recording of reflection holograms on materials with a small dimensions of nanocrystals (20-30 nm) when copying the images reconstructed of transmission holograms

Materials for monochrome recording of transmission holograms

The result: material for pulse recording in the green region of the spectrum with high sensitivity - $10^{-5} \div 10^{-6}$ J/sm^2 (diffraction efficiency - 50 ÷ 60%, nanocrystals size – 45 ÷ 50 nm).



Dependence of relative diffraction efficiency from the color tone of the object.

The advantage of holographic portraits recording in green: improving in transmission of tonal gradations in the human face.

recording in red λ=0.68 μm

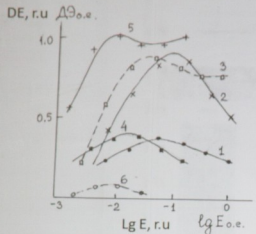
recording in green λ=0.53 μm

Materials for colored recording of transmission holograms

Applied problem - recording of colored holographic portraits.
Considered approaches:
1 - multilayer system,
2 - materials with mixed sensitization.
Results:
- decreasing of diffraction efficiency for the lower layers
- advantage of materials with mixed sensitization

№	Layer type	DE, r.u.	
		Wavelength, μm	
		0.68	0.53
1	monochrome red	1.0	-
2	monochrome green	-	1.0
3	single-layer (mixed sensitization)	1.0	1.0
4	two layers (red over)	0.7	0.8
5	two layers (red under)	0.4	0.9

Effect of additional sensitization



Additional sensitizer leads to a substantial diffraction efficiency increasing in the region of the basic sensitizer sensitivity.

The influence of additional sensitizer on diffraction efficiency.

1-3 – primary sensitization to the wavelength of 0.69 μm , additional sensitization dye 1241, 4-6 – primary sensitization to the wavelength of 0.53 μm, additional sensitization dye 1833. Recording at wavelengths 0.69 μm (1, 2, 6) и 0.53 μm (3, 4, 5), 1, 4 – curves for original layers.

Processing and characteristics

The main stages of processing:

development, bleaching.

Developers:

VRP (concentrated, diluted 1:2,1:5, 1:10), SM-6, D 82, D 19, GP 2, 8, and other.

Bleaching solutions:

PBU and on the basis of different components (iron nitrate, copper chlorine, potassium iron-synergistic, iron limono-ammonium

Holographic characteristics:

diffraction efficiency – 40 ÷ 50 % (red), 50 ÷ 60% (green),

sensitivity (corresponding to the maximum DE) 10^{-4} J/sm^2 (red), 10^{-5} J/sm^2(green).

Holographic materials for reflection holograms recording

Development and research of the material for recording in blue field

Main tasks:

1. Increasing in resolution.
   The result is a decrease in the size of nanocrystals to 10-15 nm (for comparison, PFG-03c - 30 nm)
   as a result: duration of emulsification decreasing, using of diluted solutions, synthesis at high values pAg, introduction of the stabilizer (Sta- salt)

2. Increasing in sensitivity in the blue region.
   The result is a sensitivity and diffraction efficiency increasing - to 5 $\cdot 10^{-5}$ J/sm^2
   DE - 50% (for comparison, PFG-03c - 10^{-3} J/sm^2 and 40%)
   as a result: optimization of optical sensitization, optimal sensitizer - 1610 $C_{12}H_{17}ON_3S$ (were considered for λ_{max} 460-470 нм: MA-30 6439, 1610, 109)

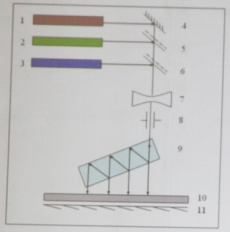
Development of material for a wide viewable area

1. Optimal optical sensitizers:

№	Chemical formula	Designation	Solubility in ethanol	Region of sensitization (nm)
1	$C_{12}H_{17}ON_3S$	1610	1:1000	400-540
2	$C_{25}H_{29}O_4N_2B_2$	1480	1:1000	460-550
3	$C_{44}H_{43}O_5N_3S_4$	2943	1:2000	530-700

2. The sequence of their introduction into the emulsion:
   1610, 1480, 2943 (blue, green, red)

Holographic characteristics

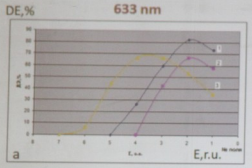


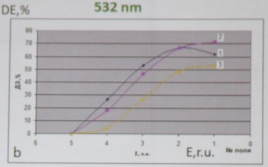
Scheme of the experimental setup.
1-3 – lasers, 4-6 mirrors, 7- lens, 8-aperture, 9- attenuator, 10 -recording material, 11- mirror.

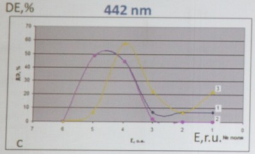
Experimental conditions

- wavelengths (continuous radiation): 633, 532, 442 , 325 nm)
- degree of stepped attenuator: 2.8
- processing : CW-C2 , PBU (amidol)
- measured parameter: diffraction efficiency
- wavelength of reconstructing radiation: 633 nm

Holographic characteristics







Diffraction efficiency exposure curves (separate recording on the one wavelength), NRC "Kurchatov Institute" materials (1, 2) and industrial materials PFG-03 C (3) "Slavich" when writing in red (a) green (b) and blue (c) regions of the spectrum.

The duration of development: 3 min (1, 3) and 6 min (2). The energy density in the first field: $8 \cdot 10^{-3}$ Дж/см^2 (а), $3 \cdot 10^{-1}$ Дж/см^2 (в), $6 \cdot 10^{-2}$ Дж/см^2 (с).

Results

1. The increase in the diffraction efficiency for the red and the green region (1.3) and the sensitivity for green and blue areas (3-4 times) compared to industrial materials (PFG-03c).
2. A lower degree of shrinkage as compared with industrial materials (visual assessment).
3. The possibility of contact processing.
4. In simultaneous recording at 3 wavelengths decrease DE less than theoretically expected (3-4 times for the red and green component and 2 times for blue).
5.The possibility of the using for recording in UV radiation 325 nm. DE- 40% (1200 l/mm) (PFG-03c -20%).

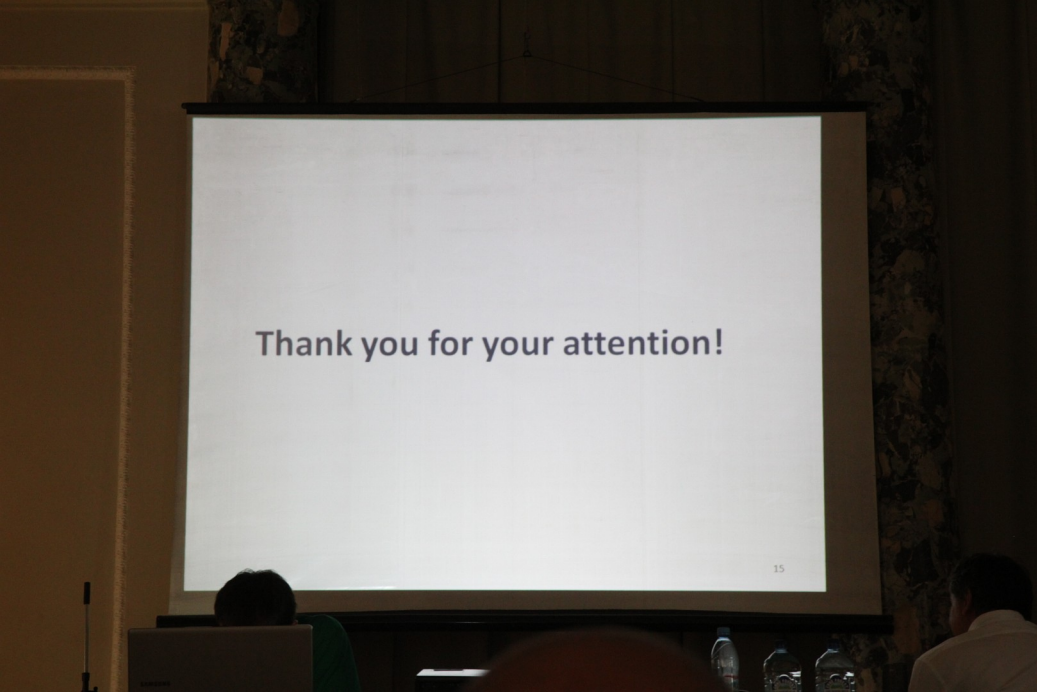
The application of the results

Holographic portrait recorded at wavelengths of 0.68 and 0.53 μm

Protective element (changes color when rotate on 90^0 around the vertical axis)

Conclusions

- Silver halide materials for colored holographic recording with continuous and pulse radiation are developed. The sensitivity of these materials is greater than that for industrial materials.
- The results can be used to solve applied problems of the holography in which the sensitivity is the determining factor (including display holography and protective technologies).


Thank you for your attention!
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