IMPROVEMENT OF OPTICAL CHARACTERISTICS OF COMPONENTS OF OPTOELECTRONIC DEVICES IN THE HARSH CONDITIONS OF THEIR FUNCTIONING BY USING ELECTRON BEAM TECHNOLOGY

УЛУЧШЕНИЕ ОПТИЧЕСКИХ ХАРАКТЕРИСТИК ЭЛЕМЕНТОВ ОПТИКО-ЭЛЕКТРОННЫХ ПРИБОРОВ В ЖЕСТКИХ УСЛОВИЯХ ИХ ФУНКЦИОНИРОВАНИЯ ПРИ ПОМОЩИ ЭЛЕКТРОННО-ЛУЧЕВОЙ ТЕХНОЛОГИИ

PhD, Associate Professor Yacenko I. V.[1] , d. Eng. Sc., Professor Antoniuk V. C.[2], d. Eng. Sc.,
Associate Professor Kyrychenko O. V.[3] , d. Eng. Sc. Gordienko V. I. [4] , d. Eng. Sc. , Professor Vashchenko V. A [1]
Cherkasy State technological university[1] , Ukraine, National Technical University of Ukraine " Kiev Polytechnic Institute name of Igor Sikorsky"[2], Cherkassy Institute of Fire Safety named after Heroes of Chornobyl[3],
Ukraine, State Enterprise scientific-production complex “Photoprylad”[4], Ukraine
E-mail: irina.yatsenko.79@mail.ru

***Summary**: The optimal parameters of the ranges of the electron beam are found (heat density, velocity, displacement), within which there is improvement of the physical and mechanical properties of surface layers of optical elements: there is no formation of negative defects on their surfaces which become atomically smooth (residual microscopic ridges do not exceed 0.5… 1.5 nm); the microhardness of the surface increases, hardened layers are formed with compressive stresses. This leads to the reduction of the light scattering coefficient of surface layers of elements and increase of their coefficient of infrared radiation transmittance and, ultimately, to the improvement of metrological characteristics and reliability of devices under intensive external thermal action.*

KEYWORDS: OPTOELECTRONIC DEVICES, OPTICAL GLASS, OPTICAL CERAMICS, ELECTRON BEAM, OPTICAL CHARACTERISTICS

1. Introduction

The areas of application of modern opto-electronic devices, which constantly expand, acutely raise the problem of enhancing of their effective functioning under harsh conditions.

Optical elements of devices under these conditions are subjected to intense external influences (elevation of heating temperature, external pressures, percussive thermal actions under conditions of supersonic airflow and axial rotation of the optical elements (hemispherical fairings, flat visibility windows etc.)).

These external influences lead to the formation on the surface of optical elements and their surface layers of cracks, chips, undulating surfaces, which violate the flatness of the elements, and other negative defects. Thereat physical and mechanical properties of the surface layers of optical elements deteriorate, and, ultimately, their optical characteristics that affect the metrological characteristics and reliability of optoelectronic devices when they are functioning under the conditions of external thermal actions [1-4].

Existing methods of improving optical characteristics of optical-electronic devices (laser range finders of sighting complexes, laser medical devices, IR-homing and tracking devices, space and aerospace grade mirrors etc.) do not always provide their normative values, especially under harsh operating conditions.

New possibilities of improvement of optical characteristics of devices are opened due to the targeted change of the physico-mechanical and thermal properties of the surface layer of optical elements by modifying it. One of the effective methods of surface treatment of optical materials is the moving electron beam, which allows to modify the surface layers of optical elements by changing its physico-mechanical properties, which influence the optical characteristics of elements, metrological characteristics and reliability of devices [5 – 13].

Phenomena connected with the influence of technological parameters of forming and physico-mechanical characteristics of the surface layer of the optical elements of the devices are not fully studied and not systematized.

This determinates the relevance of development property management methods of working surfaces of optical elements of devices by using electron-beam finishing methods of optical elements that improve the physical and mechanical properties of surface layers, increasing their optical characteristics, and resistance to external thermal and mechanical influences, that allows to increase accuracy, extend measuring ranges and improve the reliability of the functioning of the devices under intensive external thermal actions.

Therefore, the aim of this work is to improve the optical characteristics of the elements of optoelectronic devices by their finish electron beam processing.

2. Characteristics of optical elements and research methods

For experimental studies modern methods of physico-chemical analysis were used [5, 14, 15]: methods of scanning electron microscopy (SEM) and transemission electron microscopy (TEM) to study surface structure and surface layers of optical elements, as well as determine the thickness of melted layers ; methods of atomic force microscopy (AFM) and micro identification by Vickers for the measurement of the residual voids on the surface of optical elements, as well as its microhardness; shooting techniques in x-rays of diffractometers DRONE 2.0 and DRONE 3.0 for measurements of thermal stresses in the surface layers of optical elements; methods with using spectrophotometers of close (λ = 0,76…2,5 μm) and far (λ = 2,5…25 μm) of IR ranges for the measurement of transmittance factor of IR waves of optical elements; contact methods (chromel-alumel thermocouples, temperature measurement range up to 1600 K) and contactless methods (photoresistors, temperature measurement range up to 1600 K) to measure the surface temperature of the optical elements.

For finish electron beam processing of surface layers of optical elements aiming to improve their physical and mechanical properties advanced installation was used (fig. 1) in the part of developed tooling for automated measurement and control of temperature of the surface, as well as sensing the electron beam, which is protected by patents (patent of Ukraine № 57551, patent of Ukraine № 91523) [5, 6].

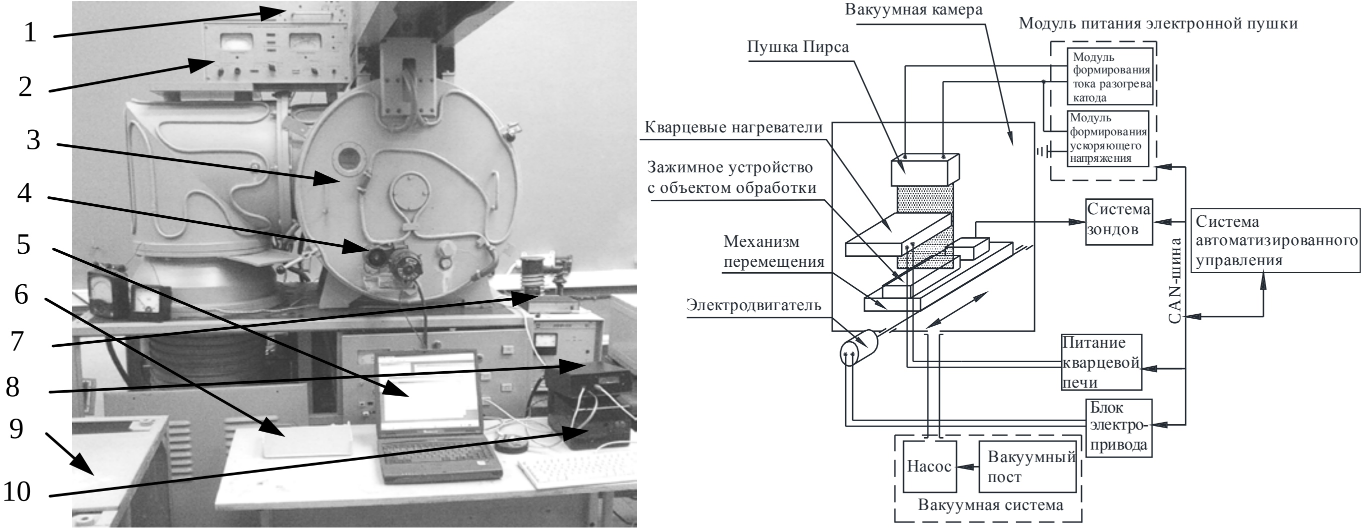
The following empirical dependencies on density of thermal influence in its center from managed parameters of electron beam installation (relative accuracy of 5…8%) were found out in the result of the research on sensing the electron beam by the known method of rotary probe [5]:

$$F_n(x)=\sqrt{\frac{k_0(I_л,l)}{\pi}}\cdot\frac{I_л\cdot V_y}{B\cdot erf\left[b(I_л,l)\cdot\sqrt{k_0(I_л,l)}\right]}, \quad (1)$$

$$k_0(I_л,l) = 1{,}237\cdot10^7\text{-}6{,}587\cdot10^5 l\text{-}3{,}725\cdot10^4\, I_л + 1{,}518\cdot10^2\, I_л\, l, \quad (2)$$

$$b(I_л,l)\frac{1{,}75}{\sqrt{k_0(I_л,l)}}\,, \quad (3)$$

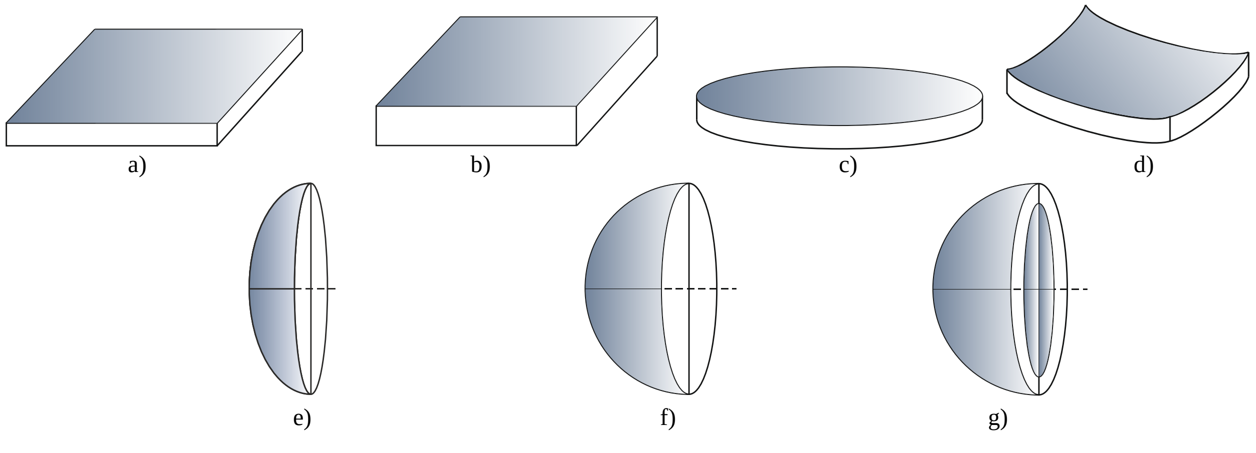
where F_n – the density of the thermal influence in the center of the electron beam, Wt/m^2; k_0, $2b$ – concentration ratio (severity of the thermal pulse) and the thickness of the electron beam, m; $I_л$ – beam current, mA; V_y – external voltage, qt; l – the distance from the processed surface of the optical element, m. Found out, that for working ranges of changing of stated parameters of installation ($I_л$ = 50…300 mA, V_y = 6...8 qt, l = 0,04...0,08 m) the following variation ranges of energy caracteristics of electron beam are realized: k_0 = (0,5…5)·10^7 m^{-2}; $2b$ = (0,5…1,5)·10^{-3} m; F_n = 10^6…10^9 Wt/m^2. Herein beam travel speed changed within V = 0…0,1 m/s.



a) b)

Fig. 1. Appearance (a) and schema (b) installations for the finishing electron-beam processing of optical elements, which improves the physical-mechanical properties of their surface layers: 1 – vacuum gauge magnetic locking VMB-8 (ВМБ-8) ; 2 – gauge ionized-thermocouple VIT-3(ВИТ-3); 3 – vacuum chamber; 4-electric mechanism of transfer mechanism of optical elements; 5 – PC control; 6 – modules of temperature measurement in the treatment area and sensing electronic flow; 7 – thermal management system of optical elements based on device RIF-101 (РИФ-101); 8 – central unit of automatic control system; 9 – power supply and control system of electronic gun of Pierce; 10 – electric motor control.

For pilot studies they used samples of optical elements of optoelectronic devices [14-18]: plane-parallel plates, rectangular, cylindrical and spherical elements elements, dual curvature elements from optical glass (K8, K108, K208, BK10 (БК10), TF110 (ТФ110)) and optical ceramics (KO1, KO2, KO3, KO5, KO12) (fig. 2).



a) b) c) d)

e) f) g)

Fig. 2. General view of the optical elements of devices: flat-parallel plates (a), rectangular elements (b), disks (c), plates of double curvature (d) (substrates, light scattering screens in micro optics, integrated and fiber optics; elements of aerospace mirrors) and spherical elements (e) – (g) (lenses, hemispherical fairings).

3. Results and discussions

Optimal variation ranges of the parameters of the electron beam are defined: heat density F_n = 7·10^6...8·10^8 Wt/m^2 and velocity V = 5·10^{-3}... 5·10^{-2} m/s, within which there is improvement of parameters of surface layers of optical elements.

Electron-microscopic studies of surfaces of optical glass elements showed that after machining the most characteristic is the presence of microflaws – cracks up to 0.1 ... 0.7 µm deep, scratches with length up to 2 ... 5 µm, bubbles in size 10^{-3}...10^{-2} µm.

After the electron beam processing the bubble sizes (diameters) on the surface of elements reduction in 2 ... 4 times, while other wavinesses less than 1 ... 2 microns are not observed, that means in electron beam processing the surfaces of elements as would be "cleaned up", tiny defects are eliminated.

In this case, when you increase the heat density F_n from $5 \cdot 10^6$ Wt/m^2 to $7 \cdot 10^7$ Wt/m^2 the area of specified defects decreases in 1,8...2,7 times.

Study of the skanogramms of grinding surfaces from elements' chipping before and after electron beam processing, show that in the first case the height of voids is 30 ...40 nm, while the latter is reduced to 0,5...1,2 nm.

Electron beam parameters influence on the height of residual voids is defined: increasing of heat density of electron beam F_n from 10^7 Wt/m^2 to $8{,}5 \cdot 10^7$ Wt/m^2 for the speed of its movement $V = 8 \cdot 10^{-3}...5 \cdot 10^{-2}$ m/s, leads to a reduction of the height of the residual voids from 3...5 nm до 1,0...1,5 nm (fig. 3 under $V = 5 \cdot 10^{-2}$ m/s (1); $V = 8 \cdot 10^{-3}$ m/s (2)).

It has been established that the maximum thickness of melted layer h_m can reach values 250 ... 300 µm, that may exceed the maximum allowable quantities of voids $h^* = 150...200$ µm, which leads to violation of flatness and geometric shape of the optical element (fig. 4 for optical glass BK10 (БК10) (1) and (2) TF110 (ТФ110) when heat density values $F_n = 5 \cdot 10^8$ Wt/m^2 и $F_n = 3 \cdot 10^8$ Wt/m^2)).

In this case, the value h_m significantly depends on the F_n and its rate of travel V: increase of F_n from $7 \cdot 10^6$ Wt/m^2 to $8 \cdot 10^8$ Wt/m^2 leads to an increase in the thickness of melted layer from 25 µm up to 230 µm; increase in running speed of the electron beam from 10^{-3} m/s до 10^{-2} m/s leads already to reduction of the depth of melting from 200 µm to 30 µm.

Found out that the electron beam generated surface layers of elements from optical glass have chemically changed structure. Thus, the analysis of the structures of layers of elements from optical glass К8, К108, К208, ВК10 (БК10), TF 110(ТФ110) showed reduced concentrations of potassium (K) and sodium (Na), which is a consequence of the instability of oxides K_2O and Na_2O, by depth action of the electron beam.

It is also shown that the electron beam processing of elements from optical glass in the result of melting of their surface layers causes the orientation adjustment near the surface of the silicon-oxygen net of the glass, which becomes close to the structure of quartz glass. Mainly this is due to the removing of ions of K, Na, as well as other elements - modifiers under the conditions of the effect of high temperatures on the surface of the elements (up to 1500…1600 K). Ultimately, this improves heat resistance of elements from optical glass.

It is determined that the effect of the electron beam on the elements of optical ceramics ($F_n = 10^6...2 \cdot 10^7$ Wt/m^2, $V = 10^{-3}...2 \cdot 10^{-2}$ m/s) leads to the increase of the microhardness of its surface depending on the parameters of the electron beam: increase of F_n from 10^6 Wt/m^2 to $1{,}5 \cdot 10^7$ Wt/m^2 leads to the increase of microhardness of ceramics surface in 1,5...1,7 times, and decrease V from $1{,}5 \cdot 10^{-2}$ m/s до 10^{-3} m/s leads to the increase of microhardness of ceramics surface in 1,3... 1,4 times (fig. 5).

It is determined that the thickness of hardened layer (Δ), where there are major structural changes and the microhardness increases of the processed material for electron beam parameters changes in the ranges from 70...90 µm to 210...230 µm in thickness of processed units $4...6 \cdot 10^{-3}$ m (fig. 6).

The value Δ depends on the parameters of the electron beam: increase of F_n from 10^6 Wt/m^2 to $2 \cdot 10^7$ Wt/m^2 leads to an increase in the thickness of hardened layer in 1,8...2,6 times, while increasing of the ray speed from $1{,}5 \cdot 10^{-3}$ m/s до $2 \cdot 10^{-2}$ m/s reduces the thickness of hardened layer in 1,7...2,5 times.

It is shown that regardless of the nature of ceramics (КО1, КО2, КО3, КО12, КО5) in the surface layers of the elements that are handled by the electron beam, for the considered ranges of density changes of heat (up to 1, $5 \cdot 10^7$ Wt/m^2) and travel speed (up to $2 \cdot 10^{-2}$ ms) notable phase changes are not observed, but the increase of the size of the crystalline grains of the material takes place. By relative expansion of lines in radiographs it is found that almost irrespective of the crystallographic directions in crystal lattices of ceramics after electronic processing there occurs noticeable change of microdeformations and mosaic block sizes (table 1).

Data from table 1 shows that the effect of the electron beam to the surface of the optical element of optical ceramics leads to the increase of mosaic blocks and the reduction of the microdeffects of lattice: value of mosaic blocks from the original to processed by electron beam of optical elements increases by 3,9 times for elements from КО2, by 5,5 times for elements from the КО2, by 3,3 times for elements from КО12, by 4,7 times for items from КО3 and 7,7 times for elements with КО5 and the value of microdeffects decreases in 3,7 times for elements from КО1, in 5,4 times for elements from the КО2, in 4,2 times for elements from КО12, in 5,5times for elements from КО3 and 5,9 times for elements from КО5.

Thereat it is found that regardless of technological modes of processing (meanings of F_n and V for the observed ranges of their change) of elements from optical ceramic in all cases, there is an increase in the size of mosaic blocks and reduction of microdeffects of their crystal lattices, i.e. as a result of electronic processing there appear more coarse-grained surface layers with strains in crystalline lattices.

Resulting from the carried out researches it was determined (fig. 7, 8) that, as a result of electron beam processing of optical elements there is an increase in such an important optical characteristics that significantly affects the metrological characteristics of opto-electronic devices as transmittance factor of infrared radiation $k_\lambda(\lambda)$ (λ – wave length) in each range of infrared transparency of optical elements (table 2).

For the elements of optical glass К8 and ВК10 (БК10) the strongest increase of the coefficient k_λ (for 20 ... 30%) is observed for the range changes λ = 0,76…2 µm and λ = 3…4 µm. For elements from optical ceramics КО1, КО2 и КО5 (values k_λ for ceramic КО3 and КО12 remain unchanged) the strongest increase of the coefficient k_λ (up to 30 ... 40 %) is observed for λ = 0,76…4 µm.

It is determined that $\overline{\Delta\lambda} = \dfrac{\Delta\lambda^{обр}}{\Delta\lambda_0} \approx$ 1,08…1,15 ($\Delta\lambda^{обр}$, $\Delta\lambda_0$ – for the elements, that are processed and not processed by electron beam электронным accordingly), so is observed small expansion range of infrared transparency of optical elements.

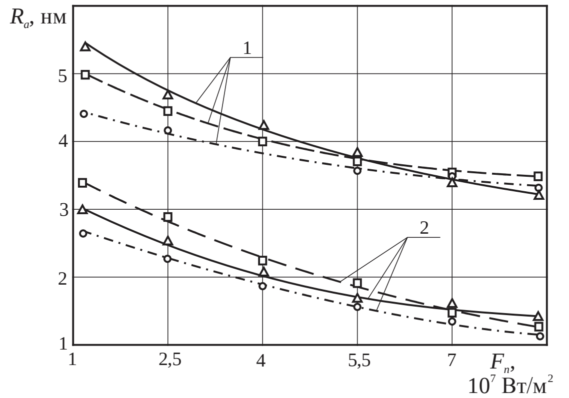


Fig.3. Height dependence of residual voids on the surface of elements of optical glass K8 (——), TF110 (ТФ110) (– – –) and BK10 (БК10) (– · – ·) from the density of heat effect of electron beam for its different travel speeds: $V = 5\cdot10^{-2}$ m/s (1); $V = 8\cdot10^{-3}$ m/s (2) (Δ, ○, □ – experimental data).

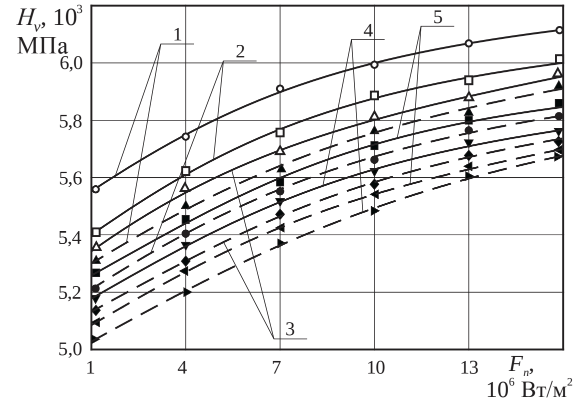


Fig.5. Dependence of microhardness surface of elements from optical ceramics KO12 (1), KO2 (2), KO1 (3), KO5 (4) и KO3 (5) at $V = 7\cdot10^{-3}$ m/s (———) и $V = 1{,}5\cdot10^{-2}$ m/s (– – –) from the density of heat effect of electron beam (Δ, ○, □, ▲, ■, ♦, ▼, ●, ►, ◄ – experimental data).

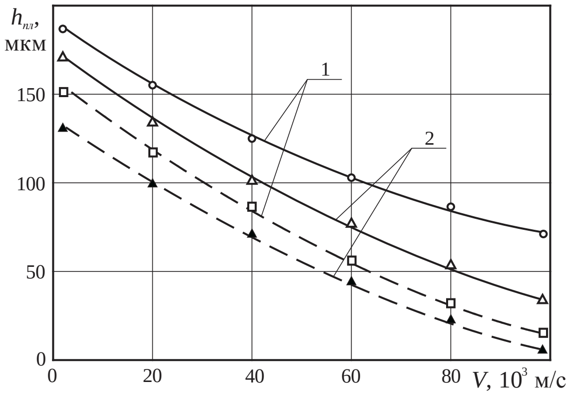


Fig. 4. The dependence of maximum thickness of melted layer in elements of optical glass BK10 (БК10) (1) and TF110 (ТФ110) (2) at $F_n = 5\cdot10^8$ Wt/m^2 (——) and $F_n = 3\cdot10^8$ Wt/m^2 (– – –) from travelling speed of electron stream (Δ, ○, □, ▲ – experimental data).

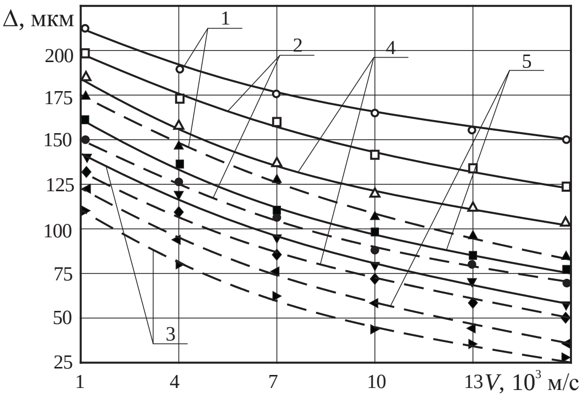


Fig. 6. The dependence of thickness toughened layers of elements from optical ceramics KO12 (1), KO2 (2), KO1 (3), KO3 (4) and KO5 (5) at $F_n = 1{,}5\cdot10^7$ Wt/m^2 (———) and $F_n = 2\cdot10^6$ Wt/m^2 (– – –) from the travelling speed of electron beam (Δ, ○, □, ▲, ■, ♦, ▼, ●, ►, ◄ – experimental data).

Table 1

The results of experimental data processing on the extension of lines on radiographs, mosaic block sizes (D) and change in the settings of a crystal lattice ($F_n = 3\cdot10^6$ Wt/m^2, $V = 3\cdot10^{-3}$ m/s)

Setting	Coarse probe			
	Physical expansion of the two lines		Block size D, $\dot{A}$	Change in the settings of a crystal lattice $\frac{\Delta d}{d}\cdot10^{-4}$
Ceramics	$\beta_1\cdot10^{-3}$, rad	$\beta_2\cdot10^{-3}$, rad		
KO1	1,472	1,734	1150	3,421
KO2	1,283	1,452	980	1,643
KO12	1,514	1,812	1240	3,810
KO3	1,120	1,320	890	1,225
KO5	1,132	1,289	760	1,117
Processed probe				
KO1	0,687	0,231	4430	0,873
KO2	0,321	0,108	5250	0,291
KO12	0,746	0,254	4110	0,992
KO3	0,224	0,986	4210	0,193
KO5	0,589	0,637	5850	0,987

Table 2

IR transparencies of optical elements $\Delta\lambda = \lambda_2 - \lambda_1$ at $H = 4\cdot10^{-3}$ m – for optical glass and $H = 10^{-2}$ m – for optical ceramics)

Element material $\Delta\lambda$, μm	K8, BK10	KO1	KO2	KO5
$\Delta\lambda = \lambda_2 - \lambda_1$, μm	5 – 0,76	7 – 2	12,5 – 2	8 – 0,76

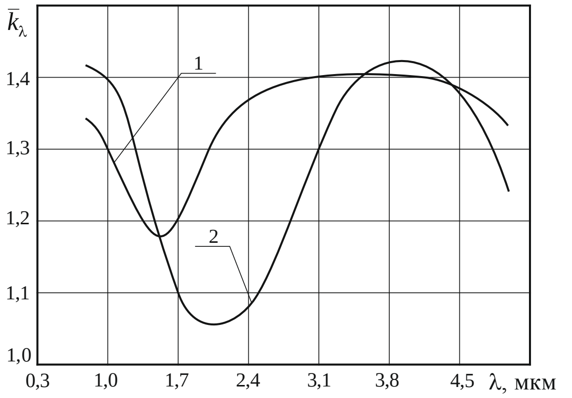


Fig. 7. The dependence of the relative coefficient of transmittance of infrared radiation through optical elements of glass К8 (1) and ВК10 (БК10) (2) (density of flat layer of element H = $4 \cdot 10^{-3}$ m; T_0 = 300 К; $\bar{k}_\lambda = \frac{k_\lambda^{обр}}{k_{\lambda 0}}$, де $k_\lambda^{обр}$ – coefficient value k_λ after electron beam machining; $k_{\lambda 0}$ – its value before electron beam machining; F_n = $1{,}5 \cdot 10^7$ Wt/m^2, V = $7 \cdot 10^{-3}$ m/s) from the wave length.

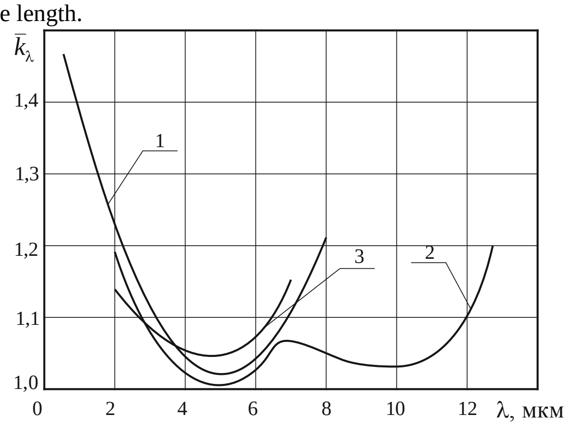


Fig. 8. The dependence of the relative coefficient of transmittance of infrared radiation by optical elements from ceramics КО5 (1), КО2 (2) and КО1 (3) (density of flat layer of element H = 10^{-2} m; T_0 = 300 К; F_n = 1, $5 \cdot 10^7$ Wt/m^2, V = $7 \cdot 10^{-3}$ m/s) from wave length.

Increase of transmittance of infrared radiation for elements from optical glass occurs as a result of reduction in the number and size of negative defects on the surface and in the surface layers (scratches, cracks, bumps, bubbles, depressions etc.) under the influence of the electron beam, which leads to their penetration. The consequence of this is a reduced number of residual voids h (nm) on their surfaces and increase of the depth of melting h_m (µm) up to the maximum permissible values of h^*. Therefore there is a one-to-one correspondence between the coefficient k_λ and such important physico-mechanical properties of the surface layers of the elements as h and h_m, which are presented in Fig. 9.

For items from optical ceramics the increase of k_λ occurs as a result of the structural changes of the surface layers (increasing sizes of mosaic blocks, layers become more compact, etc.), resulting in an increase of microhardness of their surfaces H_v and the formation of hardened layers having thickness Δ.

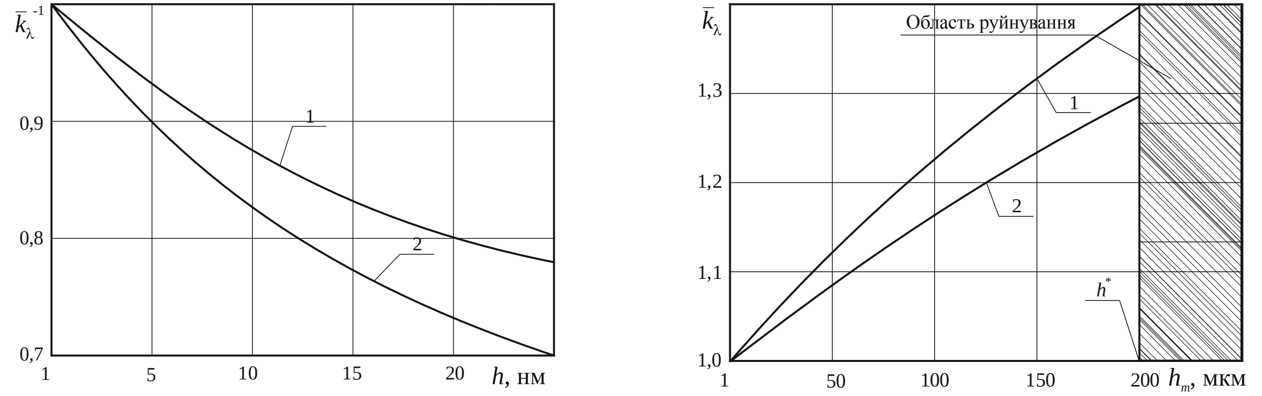
Therefore, there are also a one-to-one correspondence between the coefficient $\bar{k}_\lambda$ and parameters and H_v and Δ, dependencies between which are presented in Fig. 10.

It is determined (table 3) that after finishing electron beam processing of surfaces of optical elements of the devices out of beam parameters installed for optimal ranges of their use, deviations from the geometrical form from configured match those accepted in opto-electronic tool engineering. Thereat the surface purity of optical elements in the class P after electron beam processing increases up to one grade of purity (e.g. for photographic lenses from class VI to class V; for mirrors – with IV to III, etc.).

As a result of electron-beam processing of optical elements without reflow occurs homogenization of chemical composition of the chemical composition of hydrolysis products (dissolution of K_2O и Na_2O at depth effects of the electron beam up to 2...4 µm), which fill the defective surface layer, that remains after the standard mechanical processing, which leads to an improvement of the optical properties of the surface layers of the elements, namely to the reduction of their surface light scattering coefficient (wave length λ = 632,8 nm) (fig. 11).

In the result of the conducted research was outlined the influence of electron beam parameters to the coefficient k_c: at the increase of the parameter F_n from $7 \cdot 10^6$ Wt/m^2 to $3{,}9 \cdot 10^7$ Wt/m^2 and reduction of the parameter V from $5 \cdot 10^{-2}$ m/s to $5 \cdot 10^{-3}$ m/s the value k_c decreases in 1,3...1,5 times. In addition, reduction of the travelling speed of the electron beam leads to the increase of density influence of its thermal action in 1,2...1,3 times.

It is found out that the thermal action of the moving electron beam to the optical elements leads to their surface melting to a depth of 50 ... 200 µm, complete elimination of defective layers and reduction of micro relief of optical surfaces up to 0.5 ... 1 nm. The usage of masking and photo-and electron lithography enables create on the surface of optical elements functional micro-profiles in the form of grids, lattices, focusing lenses, and so on at a pitch of up to 100 µm.

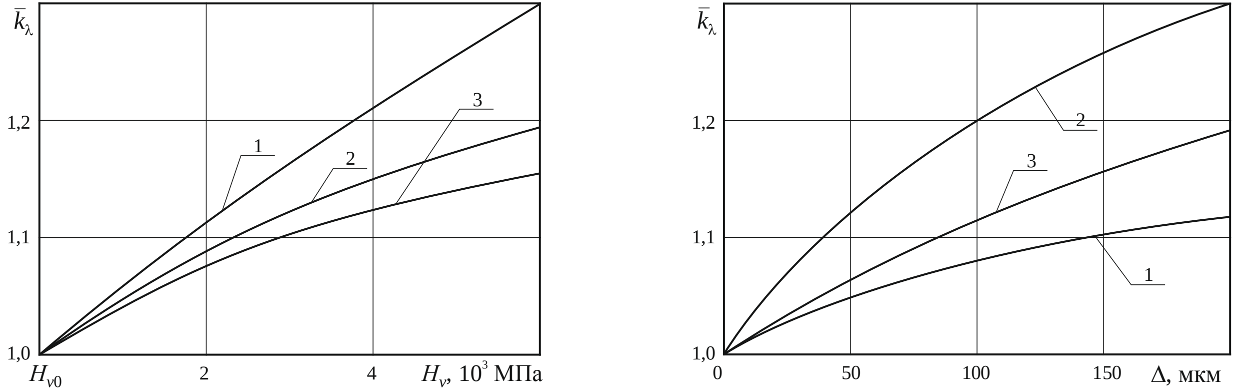


a) b)

Fig. 9. The influence of residual voids h (a) and thickness of melted layer h_m (б) to value $\bar{k}_\lambda$ for the elements from optical glass ВК10 (БК10) (1) and К8 (2) (λ = 1,06 µm).

Thus, in the light of modern technology used in optic-electronic tool engineering, electron beam processing of optical elements is defined as potentially able to improve optical characteristics of elements of optoelectronic devices (increased transmittance of infrared radiation, light scattering coefficient decrease of their surfaces, etc.), to increase their quality (compliance of geometric form with the configurated, increase of the purity and smoothness of the surface, etc.) as well as getting on the surface functional micro-profiles using electronic beams which can be used as the element base in microoptics, fiberoptics and integrated optics, optoelectronics, functional electronics etc.

In addition, the undeniable advantage of electron-beam technology is its environmental friendliness and ability to obtain microelements with improved physicomechanical properties and optical characteristics, the use of which in opto-electronic devices helps to improve their metrological characteristics and reliability under harsh operating conditions, on the common board from optical material in a single technological cycle.



a) b)

Fig. 10. The influence of microhardness of a surface H_v (a) and the thickness of the strengthened layersΔ (б) to value $\bar{k}_\lambda$ for the elements from optical ceramics КО5 (1), КО2 (2) and КО1 (3) (λ = 1,06 μm).

Table 3

The tolerance value on quality optical elements which unprocessed and processed electron beam ($F_n = 7{\cdot}10^7$ Wt/m^2, $V = 2{\cdot}10^{-3}$ m/s)

Tolerances to the surfaces of Optical elements by / Elements of opto-electronic devices		Curvature N_0, $N^{обр}$		Form ΔN_0, $\Delta N^{обр}$		Cleanliness level P_0, $P^{обр}$	
		N_0	$N^{обр}$	ΔN_0	$\Delta N^{обр}$	P_0	$P^{обр}$
Lens	red dot sights and astronomical	1 – 3	3	0,2 – 0,3	0,2	VIII	VII
	aerial photography	1 – 3	3	0,1 – 0,5	0,5	VI	V
	photographic	3 – 5	5	0,3 – 0,5	0,3	VI	V
Viewers, loops		3 – 5	3	0,5 – 0,1	0,5	V	IV
Prisms	visual	0,5 – 1	0,5	0,1 – 0,3	0,1	III	II
	refracting	2 – 4	2	0,5 – 1	0,5	IV	III
Colour-filters behind and before the viewer		5 – 10	5	0,8 – 2	0,8	III	II
Mirrors		1 – 2	2	0,2 – 0,3	0,3	IV	III

Nota bene. The following names are taken: N_0, ΔN_0, P_0, $N^{обр}$, $\Delta N^{обр}$ и $P^{обр}$ – the values of the indicators of quality of raw optical elements and processed by electronic beam, respectively.

4. Conclusions

1. New experimental data is obtained on the influence of electron beam parameters on physico-mechanical properties of the surface layers of optical elements: optimal ranges of density of heat ray, and the speed of its movements are defined, within which there is maximum improvement (more than 3 ... 5 times) of basic properties (reduction of the area of negative defects on the surface, etc.), decrease of residual voids onn the surface, increase in its microhardness, formation of hardened layers, etc.) that allows to increase the stability of the external elements to thermal and mechanical influences, thus increasing the reliability of the devices.
2. For the first time it is determined, that by controlling the physical and mechanical properties of the surface layers of optical elements using a mobile electron beam it is possible to improve optical characteristics: increase the transmittance of infrared radiation and reduce the coefficient of light scattering of surfaces of elements) that allows to improve metrological characteristics of optoelectronic devices.
3. It is defined that after finish electron beam processing of the surfaces of optical elements of devices, variations in their geometric form from the specified match those accepted forms in optical-electronic tool engineering, and the purity of elements' surface in class P increases for lenses from VI to class V; for eyepieces from V to IV class; for prisms and mirrors – class IV to III, which increases the metrological characteristics and reliability of devices by their operation.
4. It is obtained that with the help of mobile electron beam by using masking, photo- and electronic lithography, it is possible to create on the surface of the optical elements the functional micro-profiles in the form of grids, lattices, microlens focusing with the pitch up to 100 μm, that can be used as element base in microptics, fiber optics, integrated optics and optoelectronics.

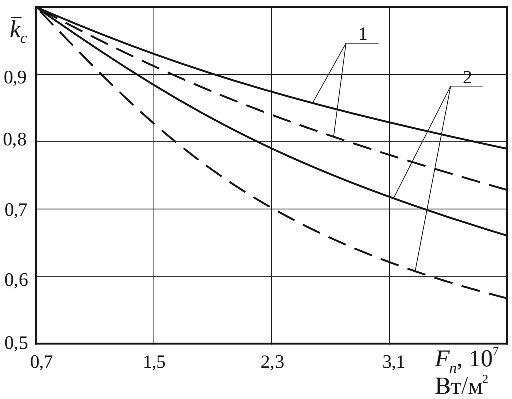


Fig. 11. Dependence of relative light scattering coefficient of working surfaces of optical elements from glass К108 (1) и ВК10 (2) the density of thermal action of electron beam for different speeds of its movement (the thickness of a flat layer of the element $H = 4\cdot10^{-3}$ m; $T_0 = 300$ K; $\bar{k}_c = \frac{k_c}{k_{c0}}$, where k_c – current value; k_{c0} – value k_c under $F_n = 7\cdot10^6$ Wt/m^2): —— – $V = 5\cdot10^{-2}$ m/s; – – – – $V = 5\cdot10^{-3}$ m/s.

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