INFLUENCE OF PARAMETERS BY ELECTRONIC RAY ON PROPERTIES OF SUPERFICIAL LAYERS OF OPTICAL ELEMENTS OF EXACT INSTRUMENT-MAKING

ВЛИЯНИЯ ПАРАМЕТРОВ ЭЛЕКТРОННОГО ЛУЧА НА СВОЙСТВА ПОВЕРХНОСТНЫХ СЛОЕВ ОПТИЧЕСКИХ ЭЛЕМЕНТОВ ТОЧНОГО ПРИБОРОСТРОЕНИЯ

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Abstract: *In the article are presented the results of researches of action of electronic ray on optical elements. The analysis of surfaces of elements before and after a beam-processing the method of atomic-force microscopy shows that in first case the height of microburries makes 50…60 nm, and in second case goes down to the level of 0,5…1 nm. Influence of parameters of electronic ray is set on the height of microburries: the increase of closeness of thermal influence of ray in 6 times results in diminishing of height of microburries in 3…4 time, diminishing of rate of movement of ray in 5 times results in diminishing of height of microburries in 5…6 times. It is shown that by optimization of the modes of beam-processing of elements it is possible substantially to improve (to 50…60%) properties of its superficial layers and basic operating descriptions of devices. Thus probability of destruction of elements and death devices in the conditions of intensive external thermal influences, devices can undergo that at their storage, portage and application, diminishes in 1,5…2 time.*

KEYWORDS*: OPTICAL GLASS, ELECTRONIC RAY, SURFACE LAYERS, ELEMENTS OF PRECISION INSTRUMENTS*

1. *Introduction*

Application expanding conditions (higher heating temperature, external pressure, thermal shock effects, etc.) devices with optical elements for measurement and control of thermal objects of different physical nature (laser modules for fiber optics, sights to observe in the visible and the infrared of the spectrum, IR-devices targeting and tracking of different objects, etc.) make high demands on their technical and operational characteristics (resistance to external heat and mechanical stress, sensitivity, reliability, etc.) [1-3]. This is because in these conditions there is a deterioration of the surface layers of the optical elements up to their destruction (cracking, chipping and other defects), leading to failure of the devices based on them.

That is the anticipation of these adverse events at the stage of design and manufacture of devices considered to optical elements is urgent. In a number of studies conducted by different authors in this direction [4-6] was found that one of the most promising directions in the elimination of undesirable changes in the properties of the surface layers of the optical elements is their finishing moving electron beam. In particular, the possibilities of an electron beam method in the formation of surface layers on the elements of optical glass with altered physic and chemical properties were shown [7].

2. *Results and discussion*

Systematic studies on the effects of the electron beam on the surface layers of the elements are very limited nowadays. Therefore, in this paper the results of studies on the influence of the main parameters of thermal effects (heat flux density, its speed), low-energy electron beam ($E \leq 10$ keV) in the surface layers of the elements of optical glass (K8, K108, K208, BK10, TF110) are presented.

In order to find the regularities of thermal influence of the electron beam on the elements of optical glass and mode control processing it is necessary to know changes in the structure of the modified layers of materials, the height of the residual microscopic irregularities on the treated surfaces of the glass and the depth of their melting depending on implemented in practice processing modes: heat flux density from electron beam $F_n = 7{\cdot}10^6 ... 5{\cdot}10^8$ Wt/m^2, the speed of its movement according to the optical elements $V = 8{\cdot}10^{-3} ... 5{\cdot}10^{-2}$ m/s. Characteristics of the studied glasses, methods of preparation of their surfaces, as well as modern methods of studies of the properties of the surface layers of glass are standard and well-known [2].

The research results of the surface elements of optical glass by scanning electron microscopy method showed that on the surface of the machined glass (K108, K208, etc.), the presence of various micro roughnesses are the most characteristic: tiny cracks of 0,1...1,5 mm depth, as well as "hillocks", bubbles, dots etc., those sizes are $3{\cdot}10^{-3} ... 2{\cdot}10^{-2}$ microns. After the electron beam treatment on the surface of the glass bubbles and points sizes (diameters) decrease in 3...5 times, the "bumps" and other unevenness smaller than 1..3 microns are not detectable, i.e. by treating the surface with an electron beam glasses they "cleared" and minor defects disappear. Surface analysis of optical glasses before and after electron beam treatment by AFM shows that in the first case, the height of asperities is 50...60 mm, and in the second case it reduces to 0,5...1 nm level. That is why the following effect parameters of the electron beam at the height of the residual microscopic irregularities (fig.1, 2) were established: the increase of the density of heat exposure to the beam up to 6 times reduces the height of the residual microscopic irregularities in 3...4 times. Reducing the speed of the beam is 5 times reduces the residual height of asperities in 5...6 times.

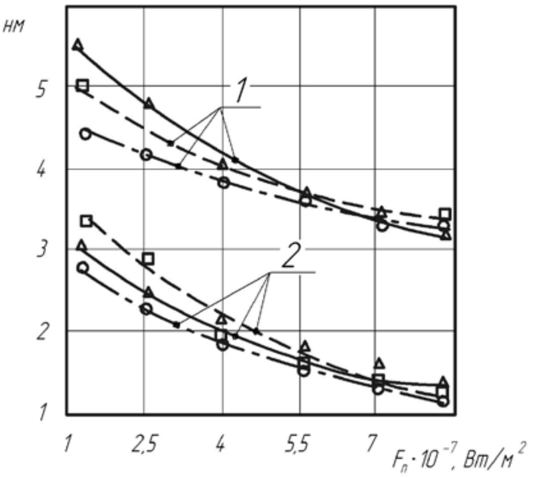

Fig.1. *The dependence of the height of the residual surface roughness of the optical elements of glass on the density of the electron beam exposure to heat: 1 – V = $5{\cdot}10^{-2}$ m/s; 2 – V = $8{\cdot}10^{-3}$ m/s; ——— – K8 glass element; – – – – – TF110 glass element; – · – · – – BK10 glass element; Δ, ○, □ – experimental points.*

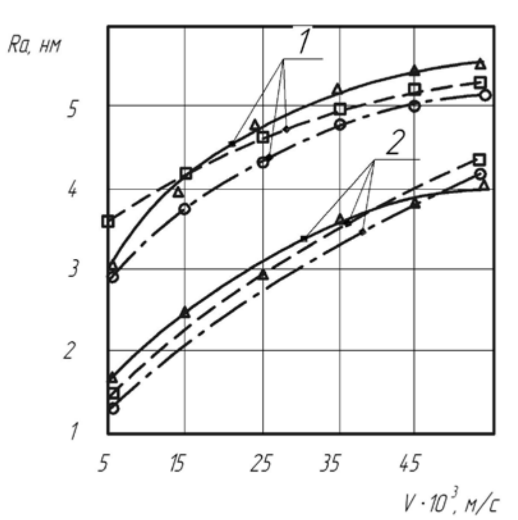

Fig.2. *The dependence of the height of the residual surface roughness of the optical elements of glass on the velocity of the electron beam: 1 – $F_n = 7 \cdot 10^6$ m/s; 2 – $F_n = 5 \cdot 10^8$ m/s; ——— – K8 glass element; – – – – – TF110 glass element; – · – · – – BK10 glass element; Δ, ○, □– experimental points.*

Study of fractogram surface layers of the optical elements of glass before and after electron beam treatment showed that the depth of the main-heat zone or the thickness of the fused layer can reach 250..300 microns and substantially depend on of the density of the heat exposure to the beam and its speed (fig.3-6): an increase in the heat exposure to the beam from $7 \cdot 10^6$ Wt/m^2 to $5 \cdot 10^8$ Wt/m^2 leads to an increase in the depth of melting of the optical element from 50 microns to 300 microns; an increasing the velocity of the beam from $8 \cdot 10^{-3}$ m/s to $5 \cdot 10^{-2}$ m/s, on the contrary, leads to the reduction in the depth of melting from 150 microns to 30 microns.

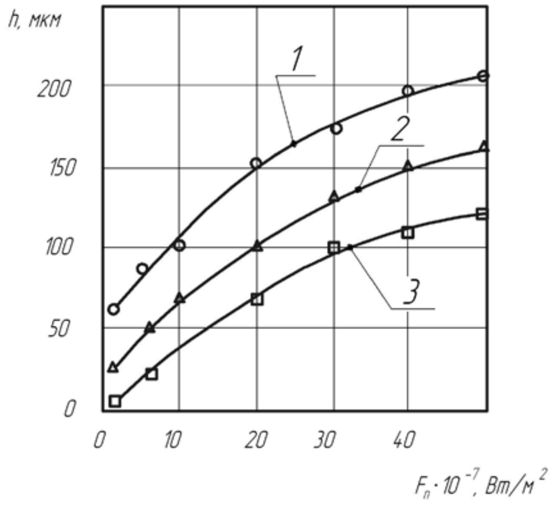

Fig.3. *The dependence of the thickness of the melted layer of the optical elements of glass on the density of the electron beam exposure to heat ($V = 5 \cdot 10^{-3}$ m/s): 1 – the element of the optical glass K8; 2 – the element of the optical glass K108; 3 – the element of the optical glass K208; Δ, ○, □– experimental points.*

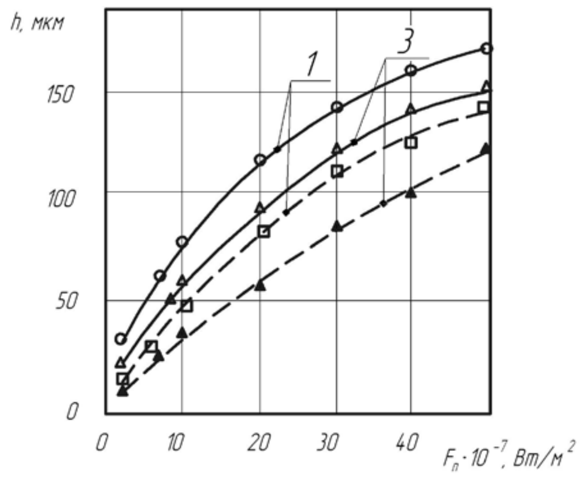

Fig.4. *The dependence of the thickness of the melted layer in the elements of the optical glasses BK10 (1) and TF110 (2) on the density of the thermal effect of the electron beam: ——— – $V = 5 \cdot 10^{-3}$ m/s; – – – – – $V = 4 \cdot 10^{-2}$ m/s; Δ, ○, □– experimental points.*

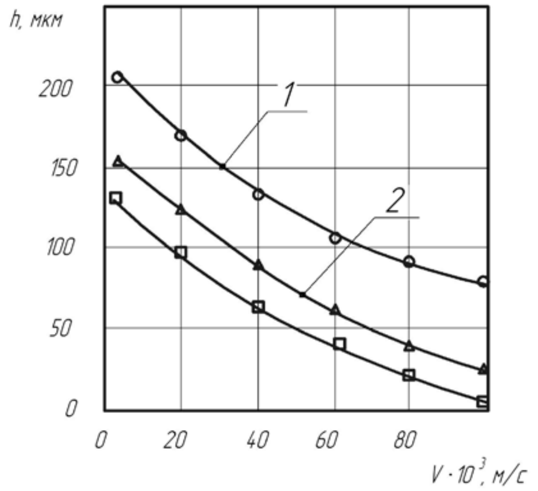

Fig.5. *The dependence of the thickness of the melted layer of the optical elements of glass on the speed of the electron beam ($F_n = 6 \cdot 10^8$ Wt/m^2): 1 – the element of the optical glass K8; 2 – the element of the optical glass K108; 3 – the element of the optical glass K208; Δ, ○, □– experimental points.*

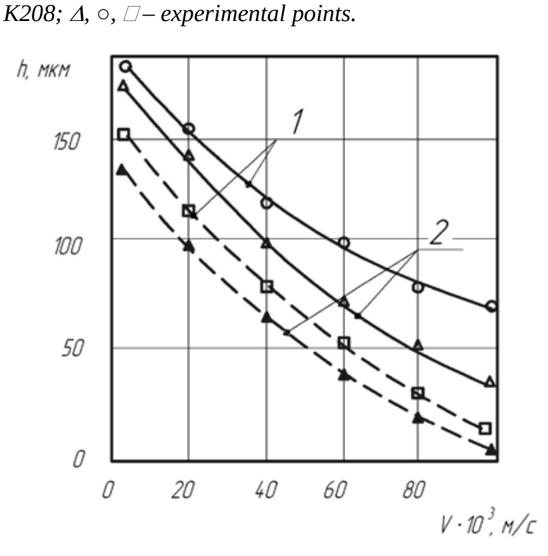

Fig.6. *The dependence of the thickness of the melted layer in the elements of the optical glasses BK10 (1) and TF110 (2) on the speed of the electron beam: ——— – $F_n = 6 \cdot 10^8$ Wt/m^2; – – – – – $F_n = 3 \cdot 10^8$ Wt/m^2; Δ, ○, □– experimental points.*

A detailed study of sections of scans surfaces of the optical elements of glass after the electron beam treatment points to the local smoothing irregularities, significant dependence on the surface shape of the processing modes. So that, with a deep melting (250...300 mm) there is a clear undulating surface of the section. That is why this modified layer has a clearly melted oriented structure depth reflow.

Thus, the electron beam, melting surface of the optical glass elements, changes the properties of the material in depth. Due to this formed with electron beam the surface layers of the elements are changed in different degree of chemical composition. Thus, the analysis of changes in the elemental composition of the glass surface K108, held with spectrometer wave dispersion showed decrease in Na and O concentration, and an increase of Si concentration and constant of K concentration. At the same time, by X-ray analysis on an example of the untreated and treated by electron beam heating BK10 it was showed that significant quantitative changes in the chemical composition of its surface was not observed, however, it is possible to conclude that the improvement of the uniformity of element distribution in micro glass surface layer after the electron beam treatment.

Spectra analysis of the concentration dependence of element distribution in the treated and untreated surfaces of the electron beam optical glass (e.g., glass K8, K108 and BK10) also indicate on the instability of K_2O and Na_2O on the depth of the electron beam exposure.

In the study of the elements of optical glass by ultra-soft X-ray reflexometer method was found that the electron beam in the treated cell the surface structure corresponds to the crystalline state, in which a violation of coordination of silicon atoms is virtually nonexistent.

It is also established that the electron beam treatment of the optical elements of glass reflow leads not only to homogenization of the surface but also to the surface oriented rearrangement in silicon-oxygen network of the glass, close to that of quartz glass, which has a high heat resistance to external-heat.

3. Conclusion

It was found that the electron beam, melting surface of the optical glass elements, changes the properties of the material in depth. Due to this formed with electron beam the surface layers of the elements are changed in different degree of chemical composition. Thus, the analysis of changes in the elemental composition of the glass surface K108, held with spectrometer wave dispersion showed decrease in Na and O concentration, and an increase of Si concentration and constant of K concentration. At the same time, by X-ray analysis on an example of the untreated and treated by electron beam heating BK10 it was showed that significant quantitative changes in the chemical composition of its surface was not observed, however, it is possible to conclude that the improvement of the uniformity of element distribution in micro glass surface layer after the electron beam treatment.

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Thus, by optimization of electron-beam processing of elements of optical glass (up to 50...60%) the properties of their surface layers and the basic technical and operational characteristics of the devices can be significantly improved. The probability of failure of elements and the failure of the devices under intense external-heat, which the units during storage, transport and use may be exposed, decreases in 1,5...2 times.

4. Literature

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