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Planarization of epilayers HgCdTe grown on CdZnTe substrates by liquid-phase epitaxy

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On samples of heteroepitaxial structures HgCdTe grown on isotype substrates CdZnTe by liquid-phase epitaxy at JSC „Giredmet", the possibility of processing the surface of the epitaxial layer of HgCdTe using submicron diamonds of detonation synthesis of domestic production for precision removal of terrace microrelief and obtaining a mirror-smooth surface with a subnano-rough relief suitable for creating IR devices is investigated.

Keywords: HgCdTe, IR devices, liquid-phase epitaxy, chemical-mechanical polishing.

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Introduction

Mercury cadmium telluride (HgCdTe) is one of the main materials for production of matrix photodetectors (MPD) of long-wavelength infrared range $8-12\,\mu$m (LWIR), which in their turn are in high demand for a wide spectrum of mostly special applications in space-based detecting devices [1,2]. Due to fundamental properties of HgCdTe: crystalline structure, direct optical transitions of a zonal diagram, change in the working wavelength depending on the composition of a triple solid solution, high coefficient of optical absorption — high quantum efficiency is provided, as well as high detecting capacity and sensitivity in production of photodetectors of MWIR and LWIR range, which increases the spatial resolution of the thermal imaging channel, thus providing for higher detection and recognition range [2]. Matrices based on such material do not require such deep cooling, as, for example, MPD based on indium antimonide (InSb), for reduction of speed of thermal generation of charge carriers, which causes reduction of mass and dimensional characteristics of instruments based on HgCdTe. The prospects of increasing the efficiency of the modern surveillance systems are related to ensuring their operability with account of the requirements of all-weather capability, jamming resistance, independence on the conditions of natural lighting and other factors. When passing through the earth atmosphere, the electromagnetic radiation weakens. Most substantial are the processes of absorption and scattering of radiation with molecules of gas, water vapors, aerosols and precipitation. The main reason for weakening of IR radiation in process of passage of ground and vertical routes consists in its absorption by gas molecules. It is the molecular absorption that determines the specific view of the spectral atmospheric transmissivity. Even under the worst weather conditions at low meteorological range of visibility the atmospheric route in IR range is more transparent than for visible light since the wavelength of radiation λ in „the transparency window" $8-12\,\mu$m is 20 times more than in the visible range $\lambda = 0.5\,\mu$m [3]. For example, if atmosphere transmits only 1% of visible light, the quantity of the transmitted IR range in the range of $8-12\,\mu$m is 22% (table 1) [4]. HgCdTe-based matrices provide the best image in the hours of darkness and in smoke and dust conditions. This expands the view of ground and air space, maintains safe piloting in complex meteorological conditions.

Advantages of the long-wavelength IR range consist in the ability to detect quickly moving objects under the conditions of low contrast target environment. In this range the noise is approximately 10 times less from radiation of heaven irregularities re-reflected from the disturbed sea surface, which is especially important to capture and track automatically the low-flying targets. In the IR range $8-12\,\mu$m the maximum of spectral radiation capacity of masked equipment and thermal radiation of human body is located [5]. The above advantages of LWIR MPDs based on HgCdTe provide for their use in production of

Table 1. Typical values of transmission coefficients for some types of radiation

Visible light $\lambda = 0.5\,\mu$m	IR radiation	
	$\lambda = 3{-}5\,\mu$m	$\lambda = 8{-}12\,\mu$m
1.0 (no fog)	1.0	1.0
0.5 (in fog)	0.67	0.97
0.1	0.36	0.56
0.01	0.01	0.22

weapon objects, military and specialized equipment and, accordingly, heteroepitaxial structures of triple compound HgCdTe are in the same row with the materials of strategic purpose, being a critical factor of economy development, state security support and included in the list of national projects of technological sovereignty development [6,7]. This explains the fact that the data related to the current state-of-the-art technology for design of such IR instruments, starting from manufacture of approved substrates, suitable for epitaxial growth of HgCdTe, production of HgCdTe layers, and ending with the MPD packaging on their basis, are practically absent in the public foreign scientific and technical literature and are strictly guarded.

HgCdTe epitaxial structures are produced by different methods.

Molecular-beam epitaxy (MBE) provides for such advantages as: relatively low growth temperature ($\sim 180\,^\circ$C), which causes reduction of impurity diffusion from the substrate, and also the cleanest conditions of growth and accordingly the low level of background doping [8]. Besides, using the MBE method it is possible to grow epitaxial structures with high accuracy, good morphology and planarity of the surface, which is most suitable for further process operations. However, MBE lays the highest requirements to the substrate, the treatment quality of which in part of surface morphology, subnano-roughened relief and geometric parameters has direct impact at production of highly perfect epitaxial structures.

In Russia the development and experimental production of HgCdTe heteroepitaxial structures by MBE method was done on Si and GaAs substrates only [9–13]. The technology of manufacturing and processing of these substrate materials is well-developed and provides for high quality of the surface compliant with the requirements of the MBE method, at relatively low cost of such substrates, which makes it possible to reduce the end cost of the instruments based on HgCdTe layers grown on Si and GaAs substrates, and also promotes the faster introduction of HgCdTe MPDs into various spheres of application. At the same time these substrate materials have high mismatch of crystalline lattices with HgCdTe (table 2) [14], chemical and temperature mismatch, which provides for the complexity of technology of HgCdTe epitaxial growth on such substrates and complicates production scaling.

HgCdTe layers grown by the method of chemical deposition from vapors of metalorganic compounds (MOCVD) are not inferior to their characteristics to the layers produced using other technologies. The advantages of this method include its flexibility and relatively high capacity, and also the possibility to produce complex multi-layer structures of high quality with moderate cost [15]. The listed advantages enable certain foreign companies to use this method for serial production of MPDs based on HgCdTe. The domestic scientific groups used MOCVD method to grow HgCdTe layers mostly on GaAs substrates [16] and, despite some publications in the domestic literature [17,18], no systematic research was done on the properties of epitaxial layers of HgCdTe, obtained on CdZnTe substrates by MOCVD-method. Currently in Russia there is growing interest to epitaxial growth of HgCdTe on CdZnTe substrates, and works are in progress to obtain non-doped epitaxial HgCdTe layers by MOCVD method on isotype CdZnTe (211)B substrates, to study the impact of the modes of pre-epitaxial treatment of substrates and conditions of deposition on the surface morphology, to determine the crystalline perfection and electrophysical properties of the layers [19].

Production of epitaxial HgCdTe layers of high quality, which is necessary to manufacture highly effective LWIR MPDs is a complex and science-intensive task, due to the formation of various structural defects, and also inhomogeneity of the composition in process of epitaxial growth. High operation characteristics of long-wavelength IR range instruments are directly determined by the quality of the surface of the epitaxial HgCdTe layer regardless of the used epitaxial method, since the quantity of defective pixels in the matrix was due to the density of defects on the surface of the grown HgCdTe layer regardless of the nature of their origin or method of layer growth [20–22]. Impact of surface defects on the photodiode characteristics increases as the size of the pixel reduces in „observing“ matrices. First of all, such defects are the main source of surface component in the high leakage current, which in its turn increases the noise and weakens the signal, thus reducing the sensitivity of the IR instrument, since the current of surface generation is due to the generation of carriers in the area of volume charge area output in the $p{-}n$-transition to the interface of semiconductor–dielectric, which is the more

Table 2. Mismatch of parameters of HgCdTe and potential substrates for its growth

Substrates	Mismatch crystalline of lattice with $Hg_{1-x}Cd_xTe$ ($x = 0.2$, $T = 300\,$K), %	Temperature mismatch with $Hg_{1-x}Cd_xTe$ ($x = 0.2$, $T = 300\,$K), %
$Cd_{1-y}Zn_yTe$ ($y = 0.04$)	< 0.1	3.53
GaAs	13.6	27.04
Si	19.47	51.85

significant, the more developed relief the surface has. The planar option of manufacturing photosensitive instruments, when there is a quality dielectric available on the surface (providing for the speed of surface recombination at the interface of dielectric−semiconductor of less than 1 cm/s) makes it possible to obtain the minimum values of the leakage currents determined only by volume properties of the material [23]. Besides, the large growth defects, the developed morphology and distortions of the surface shape (deviations from planarity), which manifest themselves in the different thickness of the epitaxial layer, increase the noise [24], being the reason for high speed of surface recombination, breaks or low quality of sputtered dielectric surfaces, cause difficulties when the photodiode matrix is joined to the signal reading circuit. The issues of surface quality management in the produced HgCdTe layers are critical in development of epitaxial growth technologies.

For complete realization of the HgCdTe opportunities, it is necessary to obtain high-quality, defect-free and possibly atomically smooth surface of this material [25]. Use of the substrates matched by the crystalline lattice parameter for epitaxial growth of HgCdTe makes it possible to reduce the density of dislocations in the HgCdTe layer to $10^4\,\mathrm{cm}^{-2}$, to provide for high structural perfection of epitaxial layers, and the homogeneity of photovoltaic characteristics by the area of the matrix (less than 0.5 % defect elements) [26]. Such isotype substrate material for HgCdTe is cadmium-zinc telluride (CdZnTe) with mole fraction ZnTe $= 3-5\,\%$ [14], and foreign manufacturers of best matrices based on HgCdTe produce this material by growth mostly on CdZnTe substrates.

In Russia the technology of epitaxial HgCdTe growth by MBE and MOCVD methods on the matched CdZnTe substrates has not been developed for a long time, since such commercially available substrates of foreign manufacture are small-size (up to 20×20 mm) and expensive, and for the last 10 years it is rather difficult to purchase them in connection with the sanction pressure. Currently within the framework of the research and developed under the assignment of the Ministry of Industry and Trade of the Russian Federation the task was solved to produce polished substrates $Cd_{1-y}Zn_yTe$ ($y = 0.04 \pm 0.005$) with diameter of 50.8 mm and crystal-lattice orientation $(211)\mathrm{B} \pm 0.5^\circ$, suitable for epitaxial processes HgCdTe by MBE method [27–31]. Parameters of substrate surface treatment quality achieved in Orion R&P Association, JSC are not inferior to the best world analogs [32–34] and are characterized by the following values: thickness difference (TTV) is $\leq 1.5\,\mu$m; surface roughness measured by atomic-force microscopy method is $Ra = 0.40$ nm ($rms = 0.51$ nm) on basic length $7\,\mu$m. Density of dislocations in the substrates is determined by the structural perfection of CdZnTe ingots grown by the Bridgman method in JSC „Giredmet“ [35,36] from extra pure pure source components of domestic manufacture [37], and is confirmed on the level below $10^4\,\mathrm{cm}^{-2}$.

JSC „Giredmet“ developed the technology of growing the epitaxial HgCdTe layers for IR receivers [38], and growth is done by the method of liquid-phase epitaxy (LPE) on the matched CdZnTe substrates with diameter of 30−45 mm and crystallographic orientation $(111)\mathrm{B} \pm 0.5^\circ$, performed using the original developed technology for the preparation of such substrates with surface roughness at the level of $Ra = 2-4$ nm [39]. The increased nano-roughened relief of the substrate surface, contrary to the requirements laid to the substrates using the MBE and MOCVD method, is explained by the fact that growing of epitaxial HgCdTe layers by the LPE method applies the preliminary dissolution of the surface layer of the substrate in the superheated solution, therefore it is permitted to use the substrates with the surface roughness of $Ra \approx 2$ nm. It was found experimentally that when the tellurium solution is superheated $< 2\,^\circ$C and the system cooling speed is $> 0.2\,^\circ$C/min, the dissolution of the substrate and subsequent growth of HgCdTe layer happen in diffusion mode, planarity at the initial stages of epitaxy is not disturbed (fig. $1, a$) [40]. Besides, the growth speed is at first negative, which corresponds to actual dissolution of the substrate in the solution, then, as the system cools down, liquid phase is oversaturated, and the HgCdTe epitaxial layer starts growing. And the growth speed passes through zero value, and this means that the system passes through the equilibrium state. Therefore, the initial stages of epitaxial layer growth occur in the conditions close to equilibrium, which is favorable for the formed microrelief. It acquires a regular wavy nature, the terrace crowns become round, and their height reduces to several dozens of nanometers (fig. $1, b$) [40]. The presence of the terrace microrelief is a specific feature of growing epitaxial HgCdTe layers by LPE method from tellurium-based solutions to a disordered CdZnTe substrate relative to the lattice plane (111) [33,41,42]. The LPE method provides for best results from the point of view of the crystalline quality and is still a common technology for serial production of HgCdTe.

Abroad there is a technology to finalize the surface of epitaxial HgCdTe layers produced by LPE method [43,44], the key results of which were presented in 2006 at the International Conference in Moscow by the technical director of French company SOFRADIR. The speaker confidently demonstrated the impact of the surface quality on the image generated by IR MPD, and the possibility to process the surface of the epitaxial HgCdTe layer with the initial terrace microrelief after LPE with the end result that is not inferior in the quality of the surface obtained by MBE method (fig. 2) [43].

Using epitaxial layers produced by LPE method and further treated, SOFRADIR company manufactured MPDs of long-wavelength IR range VENUS with working wavelength of $9.6\,\mu$m, matrix size 384×288, pixel pitch $25\,\mu$m, working temperature 80 K and quantity of defective elements in the matrix of less than 0.5 %, the appearance and spectral range of which are presented in fig. 3 [43].

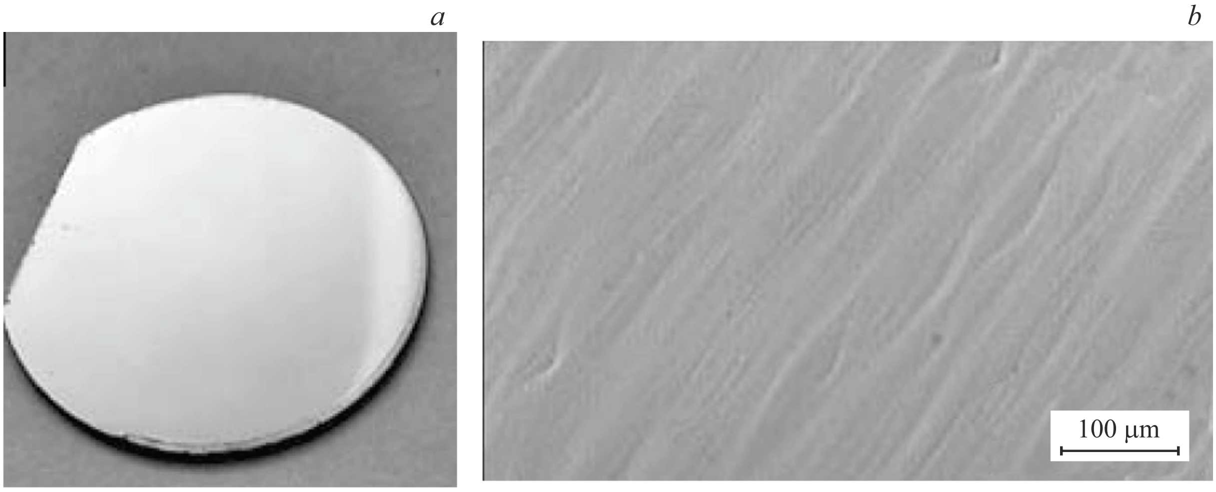

Figure 1. The epitaxial HgCdTe layer grown in JSC „Giredmet“ on the matched CdZnTe substrate using LPE method with preliminary dissolution of the surface layer of the substrate and by superheating of the solution based on tellurium 1 °C and system cooling speed 0.5 grad/min: *a* — surface shape; *b* — microrelief on the surface specific for LPE method.

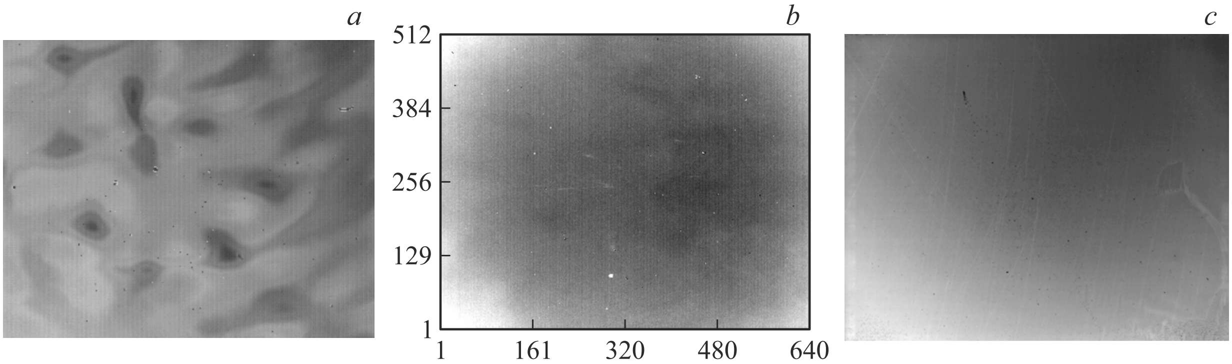

Figure 2. The surface of epitaxial HgCdTe layer on CdZnTe substrate: *a* — produced by LPE method; *b* — treated after LPE; *c* — produced by MBE method.

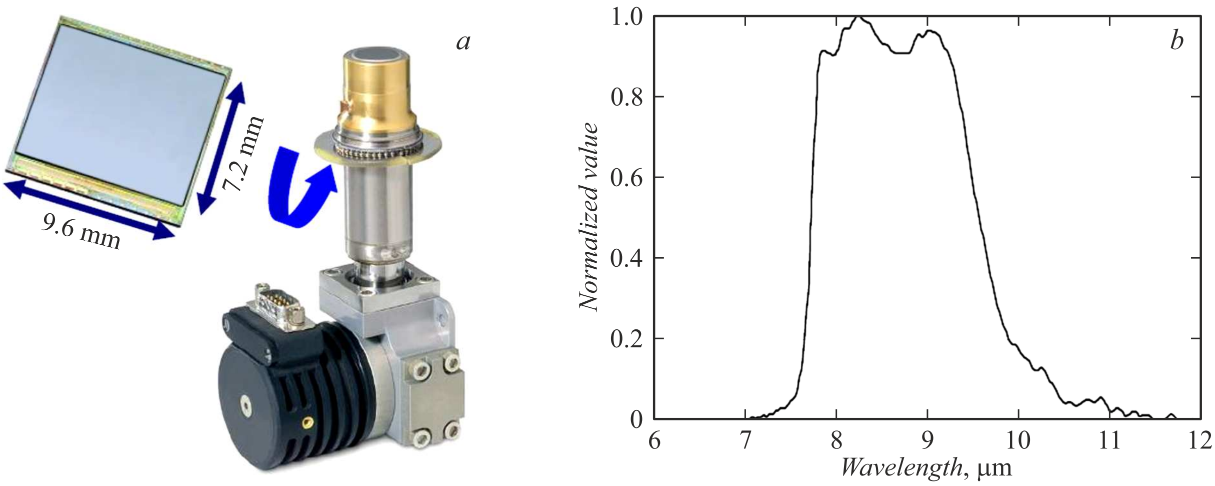

Figure 3. MPD of long-wavelength IR range VENUS based on HgCdTe, made by SOFRADIR company using technology of high quality processing of epitaxial HgCdTe layers grown by LPE method: *a* — appearance; *b* — spectral characteristic of the device.

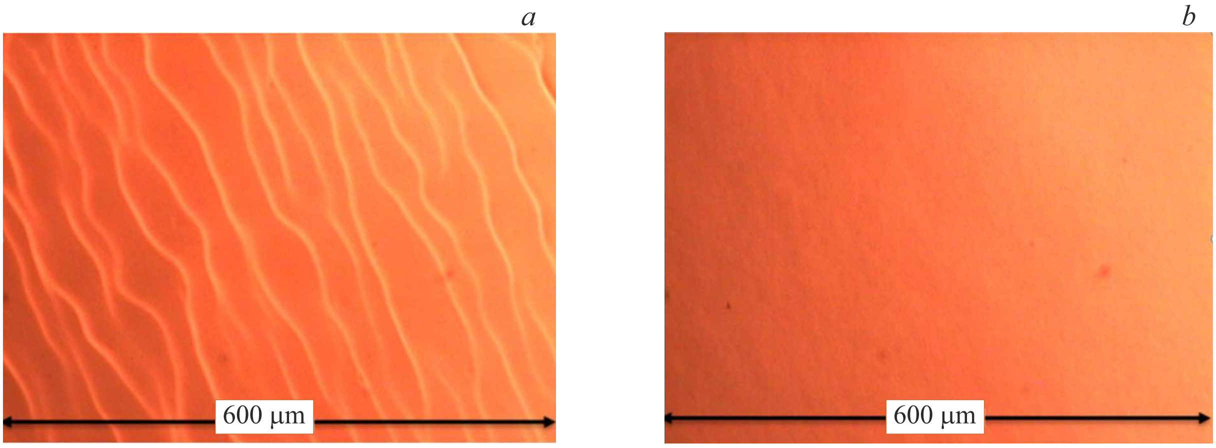

Figure 4. Morphology of the surface of epitaxial HgCdTe layer on CdZnTe substrate grown by LPE method (*a*), and morphology of the surface of this epitaxial layer after chemical-mechanical polishing (*b*).

The success of SOFRADIR company is not unique in the world. Similar results in the field of surface treatment and smoothing of terrace microrelief of epitaxial HgCdTe layers grown by LPE method were achieved by other foreign scientific groups (fig. 4) [45].

Therefore, development of MPD of long-wavelength IR range based on HgCdTe material is a relevant task aimed at strengthening of the state technological sovereignty. High-quality epitaxial HgCdTe layers suitable to manufacture LWIR MPD may be grown by various epitaxial methods using isotype CdZnTe substrates, the production of which with the requirements meeting the MBE method has been implemented in our country in the recent years. However, the technology of the epitaxial HgCdTe growth on such matched substrates by MPE and MOCVD methods, making it possible to obtain the structures with the high quality surface morphology, has not yet been developed in Russia at this time. Growth of epitaxial HgCdTe layers by LPE method on isotype CdZnTe substrates in our country using specially designed and made domestic equipment using the original technology developed in 1980–1990 under the management of V.M. Lakeenkov in JSC „Giredmet“. Nevertheless, the terrace microrelief of epitaxial HgCdTe layers at the level of $Ra \geq 10$ nm, which is a specific feature of growth with LPE method, substantially limits the possibilities to make a long-wavelength IR range on such MPD structures without surface finalization.

The objective of this study is a composite part of the studies and developments aimed at design of matrix photodetectors in the Russian Federation in the long-wavelength IR range of the spectrum based on epitaxial layers of the photosensitive HgCdTe material, grown on isotype matched CdZnTe substrates, consisted in performance of exploratory works aimed at establishment of the process possibility to use the method of chemical and mechanical polishing of the surface in epitaxial HgCdTe layers grown by LPE method on isotype CdZnTe substrates, and determination of the composition of polishing suspensions in process of the studies together with the technological conditions of the process that support the precision isotropy of the treatment, to achieve the parameters of quality in preparation of the surface of epitaxial HgCdTe layers that are not inferior to the global analogs.

1. Experimental part

The objects for the studies are presented by two different HgCdTe heterostructures grown on the matched CdZnTe substrates by LPE method in JSC „Giredmet“. The differences consisted in the diameter of the used substrates, their crystal-lattice orientation, and in the thickness of the grown epitaxial layer.

Selection of the study objects depends on the need to generate the maximum valid information under different treatment conditions and the research of the process conditions influence on the differences in the source treated materials.

For epitaxial growth of HgCdTe by LPE method it is optimal to use CdZnTe substrates with crystal-lattice orientation $(111)\mathrm{B} \pm 0.5^\circ$, and for MBE and MOCVD methods the best crystal-lattice orientation is $(211)\mathrm{B} \pm 0.5^\circ$. Use of CdZnTe substrate $(211)\mathrm{B} \pm 0.5^\circ$ to grow the epitaxial HgCdTe layers by LPE method causes strongly developed relief of the grown layer surface. The studies conducted on such specimen specially grown on the substrate with the orientation that is not optimal for the LPE method, had their purpose to improve the validity of the developed process scheme for the treatment and used technical solutions by obtaining matching results when the surface with different relief is treated.

The diameter of the selected heterostructures was 37 mm for substrate orientation $(211)\mathrm{B} \pm 0.5^\circ$ and 45 mm for orientation $(111)\mathrm{B} \pm 0.5^\circ$ accordingly. The differences in the diameter require different approach to treatment due to the brittleness of the material and the probability of the mechanical damage to the heterostructure, which increases as the diameter increases. Besides, increase of the diameter requires making corrections at the stage of the chemical and mechanical polishing, which is caused by the need to ensure mostly isotropic nature of treatment, which is achieved not only by the maximum uniform delivery of reagents to the surface and adsorption of the HgCdTe layer by their surface, but also the maximum uniform desorption of the reaction products and their removal from the surface of the treated material.

Difficulty of processing the epitaxial $Hg_{1-x}Cd_xTe$ layer is caused by the properties of this material, which is a chemical compound of cadmium telluride (CdTe) and mercury telluride (HgTe) with the adjustable width of the prohibited zone covering the IR area from the short-wavelength to the long-wavelength, and varied by selecting the quantity of cadmium (Cd) in the alloy, which tunes the optical absorption of the material to the desired length of the IR radiation wavelength. As the concentration of cadmium decreases (and accordingly the mercury quantity increases), the working wavelength of HgCdTe moves towards the IR range $8-12\,\mu$m (at $x = 0.2$). Due to weak bonds formed by mercury (Hg) with tellurium (Te), HgCdTe material is softer than any regular semiconductor A_3B_5. HgTe Moh’s hardness is 1.9, and CdTe hardness — 2.9. As mercury content increases in the triple solid solution of HgCdTe, its hardness decreases. Therefore, mechanical action at this material may cause irreversible consequences and complete loss of operation properties. Besides, HgCdTe has low heat conductivity, which decreases as cadmium concentration decreases in the content. This circumstance must be taken into account in mechanical and chemical-mechanical polishing to avoid excessive thermal exposure of the treated heterostructure.

Epitaxial HgCdTe layers were treated on PM5 Logitech (UK) unit using specially modified furniture to work in the conditions of aggressive chemical polishing etchants. In process of treatment the heterostructures were exposed to preliminary polishing with suspensions of domestic manufacture based on finely dispersed submicron diamonds of detonation synthesis. One of the typical applications of this abrasive material is the use in high precision processes to obtain surface morphology with roughness at the level of 1 nm [46–48].

Traditionally aluminum oxide powders (Al_2O_3) or synthetic single-crystal diamonds are used in the polishing of various materials. Particles of synthetic single-crystal diamond are produced by high pressure and high temperature method and have oriented crystalline structure with parallel splitting planes, which complicates disruption of such particles, besides, when disrupted, plates with sharp corner are produced, which may scratch deep the soft materials being treated. The aluminum oxide powder (Al_2O_3) is made of plate crystals, the treatment with which provides a pattern comparable with treatment by synthetic single-crystal diamonds [49].

Advantages of pre-finish mechanical polishing using suspensions based on finely dispersed submicron diamonds of detonation synthesis consists in the fact that this material has polycrystalline structure, each particle consists of multiple nanosize single-crystal units with high density of dislocations and has multiple cutting edges. In process of application at particle disruption the cutting edges are reproduced, which provides for a combination of high abrasive ability and purity of the treated surface [47]. Particles of polycrystalline diamond of detonation synthesis have pseudospherical shape, and as a result of their polycrystallinity may be easily damaged in process of treatment, forming more finely dispersed particles that have favorable effect on the morphology of the surface developed by mechanical polishing.

At the final stage the polishing of epitaxial HgCdTe layers was done with chemical and mechanical method using polishing tissue Chemcloth Logitech (UK) and the developed chemical polishing etchant of the following composition — $Br:C_2H_6O_2:CH_3OH$, where bromine concentration was 0.1 %.

After the chemical and mechanical polishing the morphology and roughness of the surface in the treated heterostructures was studied and measured in contactless optical profilometer Sensofar S Neox (Spain) with frame size of $330 \times 290\,\mu$m. Thickness of epitaxial HgCdTe layer was assessed using transmission spectra with the help of IR Fourier spectrometer Bruker Vertex 70.

The experimental specimen № 1 is presented with HgCdTe heterostructure, grown on the CdZnTe substrate of crystal-lattice orientation $(111)\mathrm{B} \pm 0.5^\circ$ with diameter of 45 mm. The results of the study of initial morphology of the surface and measurement of roughness are presented in fig. 5. The developed relief is observed, which is specific for LPE method, with roughness of the surface at the level of $Ra = 8.6$ nm ($rms = 10.53$ nm). The thickness of epitaxial HgCdTe layer made around $15\,\mu$m.

After performance of the polishing processes serially with a suspension based on submicron diamonds of detonation synthesis for planarization of the surface and chemical and mechanical polishing with application of the developed chemical polishing etchant based on bromine to remove the damaged layer, formed in process of the previous process, and also to remove microcracks, the surface of the structure became visually mirror-like with surface roughness at the level $Ra = 0.73$ nm ($rms = 0.89$ nm) (fig. 6). In process of two-stage treatment, $5\,\mu$m of epitaxial layer was removed.

The experimental specimen № 2 is presented with HgCdTe heterostructure, grown on the CdZnTe substrate of crystal-lattice orientation $(211)\mathrm{B} \pm 0.5^\circ$ with diameter of 37 mm. Two-stage treatment was also done. The appearance of the structure before and after the treatment is presented in fig. 7.

For specimen № 2 the measurements were made on the thickness of the grown epitaxial HgCdTe layer in the transmission spectra, and the thickness of the epitaxial layer after the treatment. The initial thickness

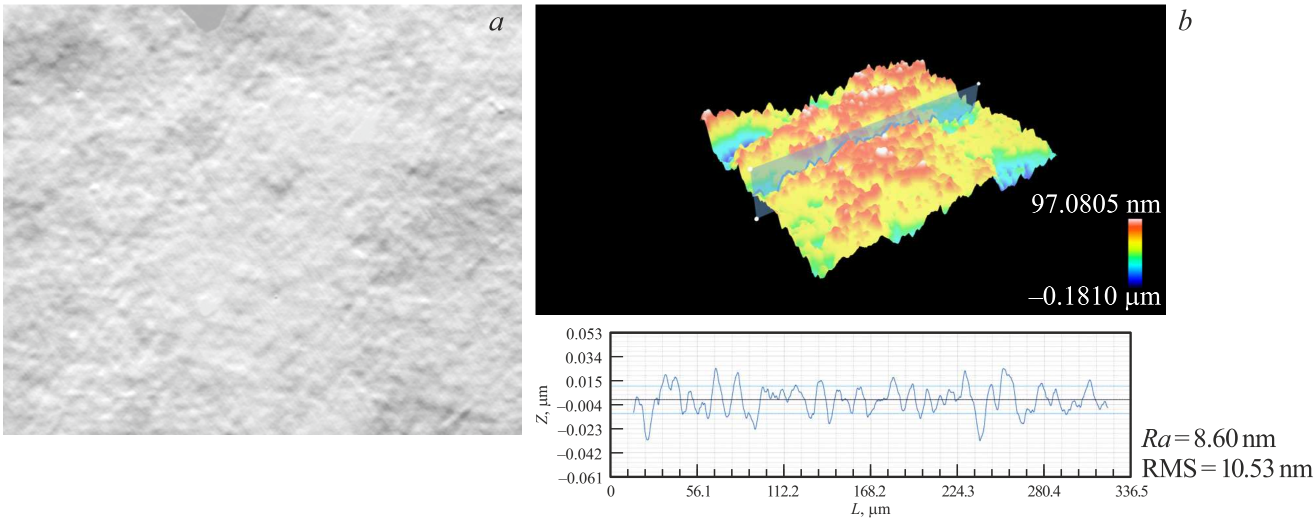

Figure 5. Morphology of the surface of epitaxial HgCdTe layer on CdZnTe (111)B substrate with diameter of 45 mm grown by LPE method (*a*), and results of surface roughness measurement in epitaxial layer (*b*).

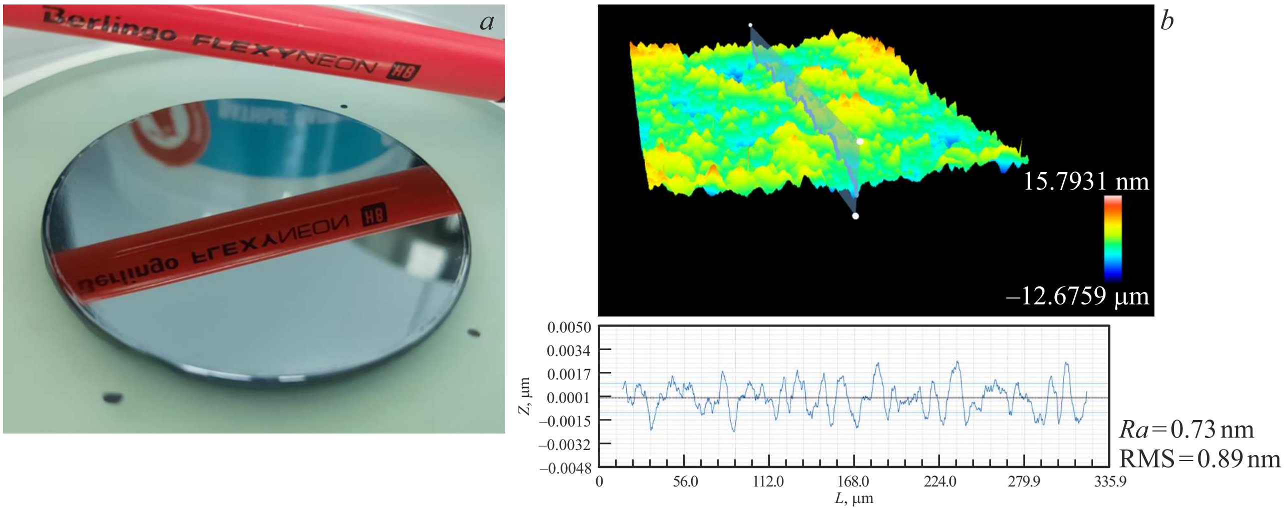

Figure 6. The surface of the epitaxial HgCdTe layer on CdZnTe (111)B substrate with diameter of 45 mm, grown by LPE method, after treatment: *a* — appearance; *b* — and results of surface roughness measurement.

of the epitaxial HgCdTe layer in specimen № 2 made 21.0–23.4 μm in different points. In some areas it was not possible to measure the transmission spectra as a result of the developed surface relief. After the two-stage treatment the transmission spectra are confidently measured in five points in the entire surface of the specimen, the thickness of the epitaxial layer was 13.4–14.7 μm, which at total removal of material at the level of 8 μm indicates a rather high precision of both preliminary mechanical polishing with suspension based on submicron diamonds of detonation synthesis, and the chemical and mechanical polishing using a chemical polishing etchant. Results of measurement of surface roughness in epitaxial HgCdTe layer of specimen № 2 were presented in fig. 8.

As you can see in fig. 8, surface roughness of epitaxial HgCdTe layer of specimen № 2 after two-stage treatment was $Ra = 0.63$ nm ($rms = 0.74$ nm). It should be noted that the developed approach makes it possible to eliminate from the surface of the epitaxial layer even a rather rough microrelief, which is specific for growing HgCdTe by LPE method on substrates with crystal-lattice orientation (211)B, presented in fig. 7, *a*.

To assess the potential distortions that could be introduced into the epitaxial HgCdTe layer, the life time was measured for the non-equilibrium charge carriers as one of the main photovoltaic parameters of the structure. It was confirmed that the life time of non-equilibrium charge carriers after the completed two-stage treatment did not change and stayed at the level of 40 ns.

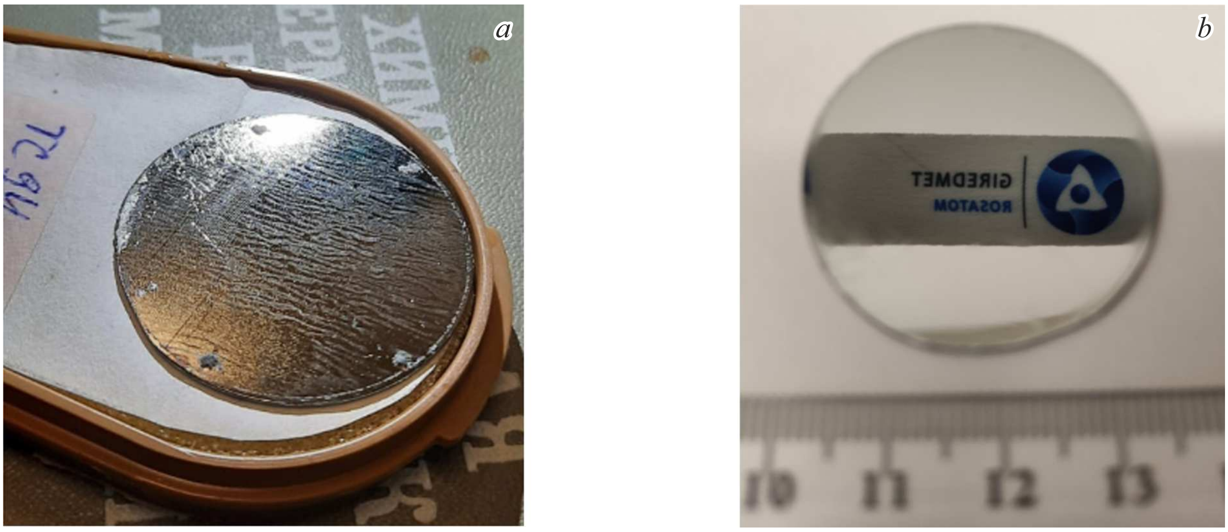

Figure 7. The surface of the epitaxial HgCdTe layer on CdZnTe (211)B substrate with diameter of 37 mm, grown by LPE method: *a* — initial appearance; *b* — appearance after treatment.

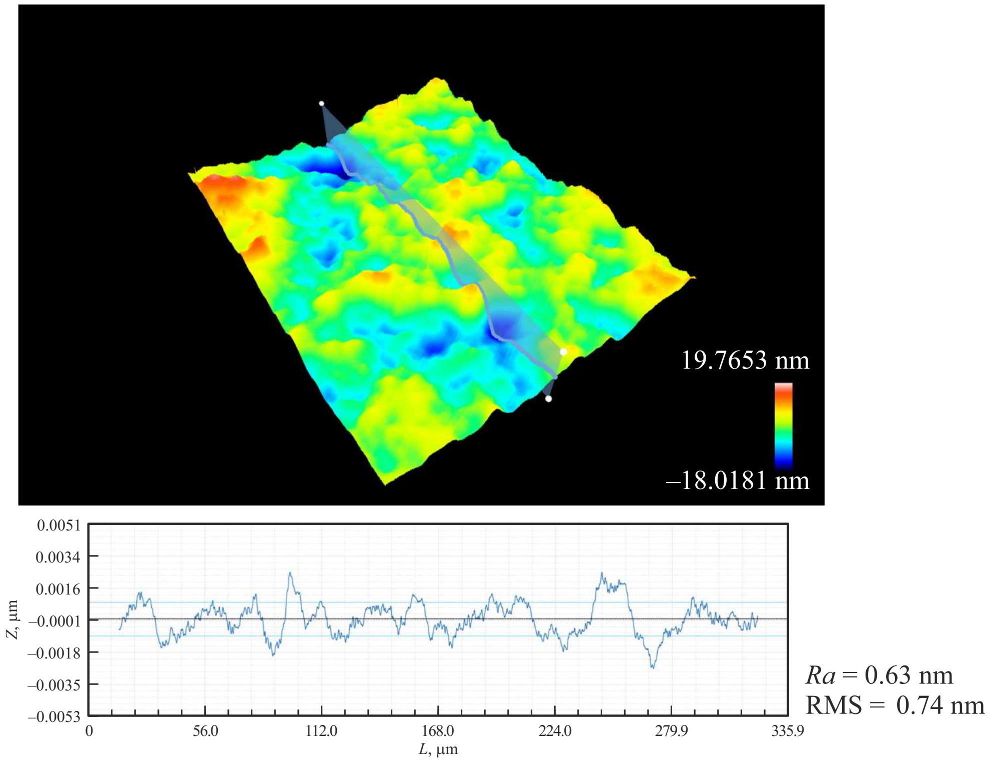

Figure 8. Morphology and roughness of surface in epitaxial HgCdTe layer, grown on CdZnTe (211)B substrate with diameter of 37 mm by LPE method, after two-stage treatment.

Conclusions

During this research, the available equipment was modified to enable operation in the conditions of aggressive chemical polishing etchants in processes of chemical-mechanical polishing, and high accuracy of the modified assembly was confirmed.

The compounds of polishing suspensions were developed in a complex with the technological conditions of the process providing for the precision isotropy of treatment, to achieve the high quality of surface treatment in epitaxial HgCdTe layers grown by LPE method.

The treatment modes were determined, which make it possible to remove the material with high precision both at the stage of mechanical polishing by suspensions based on submicron diamonds of detonation synthesis of domestic manufacture, and at the stage of chemical and mechanical polishing using a chemical polishing etchant based on bromine.

As a result of the conducted exploratory research, it was confirmed it was possible to treat the epitaxial HgCdTe layers grown by LPE method on isotype CdZnTe substrates, to produce a mirror smooth surface with subnano-roughened relief $Ra \leq 1$ nm, highly perfect on the nano-level of the surface structure, deviation of the epitaxial layer thickness by the area of heterostructure after treatment of less than 1.5 μm, without microcracks and introduced distortions into the structure of the epitaxial HgCdTe layer [50].

Conflict of interest

The authors declare that they have no conflict of interest.

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