

QUANTITATIVE SPECTROSCOPY OF THE ELECTRON-INDUCED PROCESSES ON THE SURFACE OF WIDE-BAND-GAP INSULATING MATERIALS

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We investigate the electron-induced processes on the surface dielectric films of MgO and CsI_xBr_{1-x}(Cd). The results of quantitative Auger-electron spectroscopy (AES) obtained by pure elemental standards within the method of matrix corrections for the films of MgO and CsI_xBr_{1-x}(Cd) are compared with those derived for single crystals. We identify electron-relaxational processes by the method of thermally stimulated exoelectron emission (TSEE) and electron-stimulated diffusive and destructive processes by the quantitative AES method. Such processes on the surface and in a near-surface layer of dielectric crystals and films cause certain changes in the stoichiometry of the surface under electron irradiation.

On the surface of solids, the following processes occur under the electron irradiation: the destruction of the surface with respect to certain components, creation of surface radiation-induced defects, migration of atoms on the surface and their diffusion, reaction on surface, and formation of interfaces [1,2]. The comprehension level of the indicated processes and many other ones defines the progress in such important field as planar micro- and nanoelectronics [3].

The study of dielectric film and crystal materials used for the representation, recording, and transformation of the information in miniaturized optoelectronic and photonic devices with high information-related capacity is carried on [4], as well as highly efficient radiation-resistant film dielectric coatings [5,6]. After the discovery of the intense photostimulated luminescence of X-irradiated doped crystal CsBr(Eu), its application to the recording of the information by X-emission becomes promising [7]. The crystals of the solid solutions of CsI—CsBr in certain concentrations are used as efficient scintillation materials in the transformers of ionizing radiation (electrons and γ -quanta) [8]. Therefore, the studies of radiation-stimulated changes and mechanisms of their running in near-surface layers of dielectric materials under the electron irradiation are topical up to now

[9,10]. To clarify them, we use the methods of electron-emission spectroscopy, in particular AES and TSEE.

1. Objects and Methods of Investigations

The objects under study were the cleavage surfaces $\approx 1 \times 3 \times 4$ mm, which were derived in air from pure crystals MgO(100), and polished monocrystalline plates $\approx 0.6 \times 4 \times 8$ mm cut from the crystals of the solid solutions of CsI_xBr_{1-x}(Cd). We also investigated the dielectric films of these compounds produced by certain technological methods. The thin films of MgO were produced by high-frequency ion-plasma spraying and also applied by the aerosol method to molybdenum substrates. The films of the solid solutions of CsI_xBr_{1-x}(Cd) of $d \leq 1 \mu\text{m}$ were derived by the method of thermal evaporation of the monocrystalline specimens of CsI_xBr_{1-x}(Cd) into vacuum and the subsequent deposition of vapors on molybdenum substrates.

The specimens fixed on holders-accessories after the thermal vacuum processing in the air lock high-vacuum (HV) chamber (1×10^{-7} Torr) of a two-chamber Auger-spectrometer 09IOS-2 were studied in the HV chamber (TSEE) or were moved with the use of the rod of a manipulator into a ultrahigh-vacuum (UHV) chamber and studied (*in situ*) by AES in vacuum 1×10^{-9} Torr.

The experimental setup for the “study of the element-phase composition of the surfaces of solids, radiation-induced physicochemical processes on the surface and the processes of formation of interfaces” was described in [11] in detail together with its functional block-scheme. The setup was mounted on the base of an Auger-electron spectrometer 09IOS-2 with the incorporated channels, in addition to the serial AES channel, of mass-spectrometry (a mass-spectrometer of the type MKh7304A); the gas bleed-in channel (balloons with Ar, O₂, and CO

and the two-channel gas bleed-in system SNA-2), photoelectronic spectroscopy (a xenon lamp XRM-P with $h\nu = 8.43$ eV, a monochromator on a diffraction grating MUM-1 (1.55–6.2 eV), and exoelectronic (mechano-, photo-, and thermally stimulated) emission spectroscopies of surfaces.

By AES, we studied a change of the stoichiometry of the surface of thin films and crystals of compounds after their contact with air (the transfer of the films through air and the derivation of the surfaces of crystals in air) and after the action of various doses of electron irradiation *in situ*. The method of AES is an analytical method of study of the element-phase composition of surfaces which presents a possibility of the quantitative analysis of their elemental composition [12, 13]. The Auger-spectra of the surfaces were recorded in the mode of differentiation of the energy spectra of emitted electrons $dN(E)/dE$ upon the resolution power of an energy analyzer of the cylindrical-mirror type $\Delta E/E \approx 0.5\%$ and at the energy of exciting electrons of 3 keV. The electron beam probing the surface also induced some changes depending on its density. The density can be varied in the range $10\text{--}10^3$ A/m² upon the change of the beam diameter in the plane of the specimen surface from 20 to 40 μm .

The main chamber of an Auger-spectrometer for the control over the composition of the gas atmosphere was supplemented by a mass-spectrometer MKh7304A. To derive pure “radiation-undamaged” surfaces, the specimens of MgO and CsI_xBr_{1-x}(Cd) were positioned in the air lock chamber in vacuum 1×10^{-7} Torr, subjected to the cyclic thermal processing at (295–750) K, and held at (630–650) K for 5 h. The thermally desorbed gases, which were adsorbed upon the transfer of the specimens through air, contained mainly molecules H₂, H₂O, CO, and CO₂ which were registered by mass-spectrometry. The effect of the electron irradiation dose ($j = 10^2$ A/m², $E = 3$ keV) on the stoichiometry of the specimen surface was studied in the SNV chamber of a spectrometer *in situ* in the atmosphere of residual gases 1×10^{-9} Torr controlled by a mass-spectrometer.

The TSEE spectra after various doses of the electron irradiation of specimens were recorded in the range 295–650 K under the heating by a linear law with the rate $\beta = 0.08$ K/s in the precedent (air lock) chamber of a spectrometer. As a detector of exoelectrons, we used a channel secondary-electron multiplier (SEM) of the VEU-6 type with a channel of the spiral type which operated in the mode of counting of electrons. The coefficient of amplification of a SEM at a feeding voltage

of 3.5 kV reached 7×10^8 , which allows us to register emissive currents of the order of 10^{-19} A.

The Auger-spectra in differential form $dN(E)/dE$ were registered at the modulation amplitudes $U_m = 2$ V for Auger-peaks Mg(27 eV), Br(55 eV), S(152 eV), Cl(181 eV), C(270–272 eV), Cd(376 eV), O(507 eV), I(511 eV), and Cs(563 eV) and $U_m = 6$ V for Mg(1172 eV) and Br(1396 eV), respectively. Such voltages U_m , which modulate the flux of secondary electrons, do not lead to the “overmodulation” of signals of the current of Auger-electrons [14, 15] and allow us to get the “peak-peak” amplitudes of Auger-electrons of the above-indicated elements which represent properly the derivatives $dN(E)/dE$. Under such conditions of the registration, the differential spectra of Auger-electrons of the chemical elements are proportional to the currents of their Auger-electrons. Thus, the use of the “peak-peak” amplitudes of Auger-electrons for the quantitative Auger-analysis is correct. According to [14, 15], the limit value of U_m is equal to 4.3 V for the peaks of Auger-electrons Mg(27 eV), Br(55 eV), S, Cl, C, Cd, O, I, and 8.6 V for Cs Mg(1172 eV) and Br(1396 eV).

The quantitative Auger-analysis was performed by using the experimental spectra of Auger-electrons from surfaces with the measurement of the peak-peak amplitudes of elements and by using the database [12,16] and the software described in [13] in detail. The developed method of quantitative Auger-spectroscopy (the method of pure standards with matrix corrections) allows us to get the relative concentrations of chemical elements on the surface from their relative peak-peak amplitudes.

2. Results of Studies and Discussion

By the methods of electron-emission spectroscopies, AES and TSEE, we studied the cleavage surfaces $\approx 3 \times 4$ mm, which were derived in air from the crystals of MgO(100), and the films of MgO of the thickness $d \leq 1$ μm , which were derived by the high-frequency ion-plasma spraying with violation of the stoichiometric composition to the side of the excess of Mg, as well as the films which were deposited by the aerosol method and included the phase Mg(OH)₂ and hole $V_{\text{OH}^-}^-(v_c^{2-}e^+)$ -centers (a hole e^+ is localized near a cation vacancy v_c^{2-} on an impurity anion OH⁻ which is present in the lattice of MgO instead of O²⁻) [17,18].

The stoichiometry of the crystal surface and the films of MgO and the presence on the surface of extraneous impurities and contaminants were controlled by AES (Mg, O, S, and C), and the phase of hydroxide

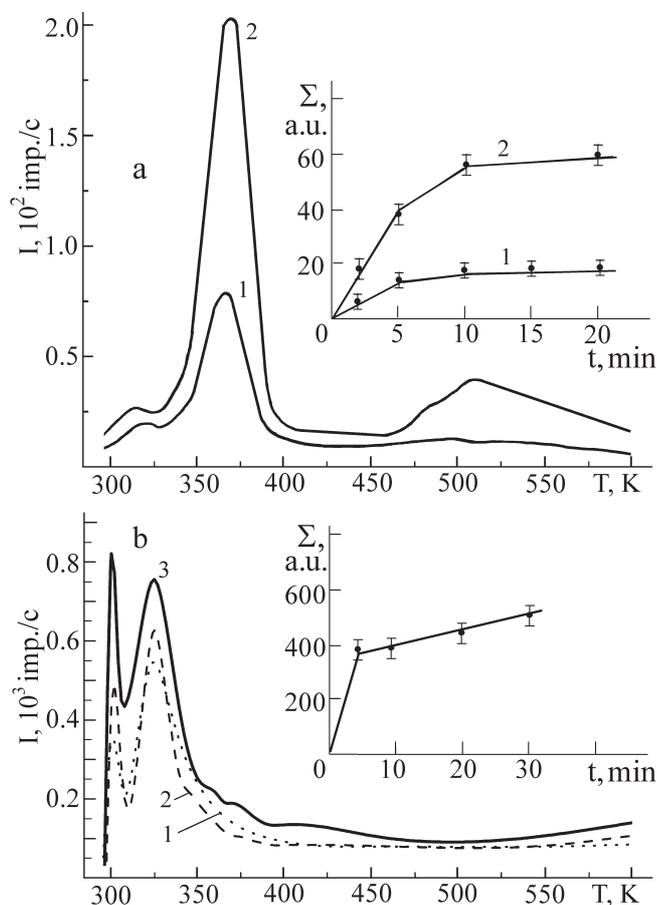
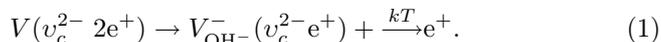


Fig. 1. *a* – TSEE spectra of the films of MgO after the electron irradiation ($j = 10 \text{ A/m}^2$; $E = 2.5 \text{ keV}$) for 1 and 10 min (curves 1 and 2, respectively). The insert shows the exosum as a function of the dose of the electron irradiation for a single crystal 1 and films 2 of MgO; *b* – TSEE spectra of crystals of the solid solution of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$ after the electron irradiation ($j = (1.2\text{--}1.3)\times 10^{-2} \text{ A/m}^2$; $E = 2.5 \text{ keV}$) for 5, 10, and 30 min (curves 1, 2, and 3, respectively). The insert shows the exosum as a function of the dose of the electron irradiation

$\text{Mg}(\text{OH})_2$ and molecular anions (OH^- , O_2^{2-} , and CO_2^{2-}) in films were studied by the methods of IR-spectroscopy (Specord-75) [17,18].

As a result of the dissolution of H_2O and CO_2 during the derivation of the films of MgO, the anion impurity defects (OH^- , O_2^{2-} , and CO_2^{2-}) are formed in the films. In the films derived in air by the aerosol method, we observed the inclusions of H_2 , H_2O , and CO , as well as the phase $\text{Mg}(\text{OH})_2$. Under the heating of films in vacuum at 720 K ($t > 60 \text{ min}$), this phase decays with the creation of hole $V_{\text{OH}^-}^-(v_c^{2-}e^+)$ -centers. A hole $V(v_c^{2-} 2e^+)$ -center localized at a cation vacancy v_c^{2-}

is unstable and can decay already at 295 K [9] with the creation of thermally activated movable holes which can initiate Auger-like recombination processes with the exoemission of electrons [17–20]:



Upon the comparison of the IR-spectra of the crystal of MgO and the films, the presence of the phase $\text{Mg}(\text{OH})_2$ and $V_{\text{OH}^-}^-(v_c^{2-}e^+)$ -centers was revealed by the appearance of new absorption bands at 3700 and 3296 cm^{-1} , respectively [17,18].

By mass-spectrometry, we observed the separation of some components of the impurities (H_2 , H_2O , CO , CO_2) under the thermal cycling and the electron irradiation of the films of MgO. The irradiation ($j > 10 \text{ A/m}^2$, $E = 3 \text{ keV}$) induces the processes in the near-surface layer with the creation and the subsequent desorption of CO , which can be described by the quasichemical reaction



where O^-/MgO is the defect surface form. As a result, the vacancy of Mg (v_c^{2-}) is created with a localized hole, i.e. a hole $V^-(v_c^{2-}e^+)$ -center. In addition, under the irradiation, there occur the disintegration of H- and C-containing molecules, radiation-induced shaking, and diffusion of hydrogen and carbon, which yields to the creation and evolution of methane. The curves of electron-stimulated desorption of CO and CH_4 approach rapidly a saturation level depending on the current density.

Thus, the electron irradiation of the films of MgO leads to the purification of the surface. As a result of the electron-stimulated desorption and the creation of “bulk centers” in the near-surface layer, namely the hole centers [$V^-(v_c^{2-}e^+)$, $V_{\text{OH}^-}^-(v_c^{2-}e^+)$, and $V(v_c^{2-} 2e^+)$] and the electron ones [$F(v_a^{2+} 2e^-)$ and $F^+(v_a^{2+} e^-)$] on the basis of “biographic” impurity-type and vacancy-type defects, the latter being represented by cation and anion defects (v_c^{2-} , v_a^{2+} -vacancies).

The typical TSEE spectrum of the films of MgO after the action of various doses of the electron irradiation ($j = 10 \text{ A/m}^2$, $E = 2.5 \text{ keV}$) is given in Fig. 1, *a* and indicates the presence of both the hole-induced recombination Auger-like exoemission of electrons and, respectively, hole and electron centers [19, 20]. The TSEE of the films of MgO is mainly conditioned by the hole-induced recombination Auger-like processes involving the elementary centers of the defect-impurity origination by the general scheme $[V, F] \rightarrow (F)$.

These centers appear after the disintegration of more complicated impurity complexes under the electron irradiation. We denote a recombining pair of defects by the square brackets and an electron center, which is ionized by the recombination energy, by the parentheses [19, 20]. In addition, TSEE is also caused by the thermal ionization of shallow surface electron traps $F_s(v_a^{2+} 2e^-)$ and $F_s^+(v_a^{2+} e^-)$ filled under the electron irradiation and such that are thermally ionized under the heating [19]. TSEE increases firstly with the irradiation dose. In this case, the “structure” of TSEE spectra varies slightly. Then the exosum reaches the saturation level and it almost is not changed as the dose grows (Fig. 1). The exosum of emitted electrons was determined as the area under the curve of TSEE $I_{\text{TSEE}}(T)$ in the range (290–600) K:

$$\Sigma = \int_{290}^{600} I_{\text{TSEE}}(T) dT. \quad (3)$$

This testifies to that the TSEE of the films has the “defect-impurity” nature, and the electron irradiation with the indicated doses [$G(j) \leq (3 \div 5) \times 10^6$ Gy/s] creates no natural (fundamental) radiation-induced defects in MgO. The electron irradiation dose D absorbed by the near-surface layer and the dose rate G were estimated as [10]

$$D = \Delta W / \Delta m = jUt / \rho d, \quad \text{and} \quad G = \Delta D / \Delta t, \quad (4)$$

where ΔW is the irradiation energy which is transferred to the near-surface layer of a material with mass Δm ; U of the accelerating voltage acting on electrons; t is the irradiation duration; ρ is the material density; and d is the energy-dependent penetration depth of electrons. It is worth to note that, in the radiation physics and chemistry of surfaces irradiated by ionizing particles, the fluence $\Phi = j \times t$ (j is the particle flux density) is of the same importance as the radiation dose. Therefore, we present both parameters, the dose and the fluence, in Figs. 2 and 3, because we study the radiation-stimulated processes on the surface and in near-surface layers.

The TSEE spectrum of the cleaved monocrystalline specimens of MgO thermally processed and irradiated by electrons in vacuum has almost the same structure as that for the films, but it has much lower intensity at the maximum of TSEE ($I < 80 \div 100$ pulse/s) and “is exhausted” with increase in the radiation dose. This is clearly seen on the dependence of the exosum of emitted electrons on the dose (duration) of the electron irradiation (see the insert in Fig. 1, *a*).

The TSEE spectra of the specimens of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$, which are thermally processed and irradiated in vacuum, are given in Fig. 1, *b* and have much higher intensity at the maxima of TSEE, than that for MgO, even for much lower current densities under the irradiation (excitation). This testifies to the lower radiation-resistance of the specimens of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$ as compared to that of MgO. Moreover, the increase in their exosum with the radiation dose indicates the creation of natural (fundamental) radiation-induced defects, whose concentrations increase with the radiation dose. Their exoemission mechanisms are similar and differ only by the participation of the natural complementary pairs of radiation-induced defects in the recombination processes in the case of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$ [20]. Finally, we note that exoelectronic emission spectroscopy is valuable for that it gives the information on the energy nonequilibrium of surfaces (near-surface layers) after the action of the ionizing irradiation (of electronic, ionic, photonic probes). The appearance of the exoemission current accompanies the relaxation processes under the recombination annealing of defects of the surface (the analysis depth is equal to (10–100) nm [10]) and allows one, in certain cases, to register their surface concentrations on the level of $10^{10} \text{--} 10^{11} \text{ cm}^{-2}$ [10]. Thus, the exoemission allows one to register the initial stages of the surface formation of defects and the destruction of the surface. Moreover, the method of isothermal or thermally stimulated exoemission is a relaxation nondestructive method which accompanies (reveals) the relaxation processes on the surface.

Changes of the stoichiometry of the surface of MgO under the electron irradiation were studied by AES. The characteristics of the electron beam probing the surface are as follows: $j = 10^2 \text{ A/m}^2$, and $E = 3 \text{ keV}$. The typical spectrum of Auger-electrons of the surface of monocrystalline MgO (the fragments of the Auger-peaks of main registered elements) is presented in Fig. 2 (see fragment 2). The relative changes of the surface concentrations of the components, Mg and O, under the irradiation of MgO were determined by the change in the amplitudes of their reference peaks: Mg(1172 eV) and O(507 eV). That is, the change in the concentration of oxygen was determined by variations in the amplitude of its characteristic Auger-peak O (507 eV). The concentration of Mg “can” be determined in two ways: by the change in the amplitude of the peak Mg(27 eV) or Mg(1172 eV). The choice of the peak Mg(27 eV) to analyze the stoichiometry is not correct, because it is related to “skew” Auger-transitions between the two

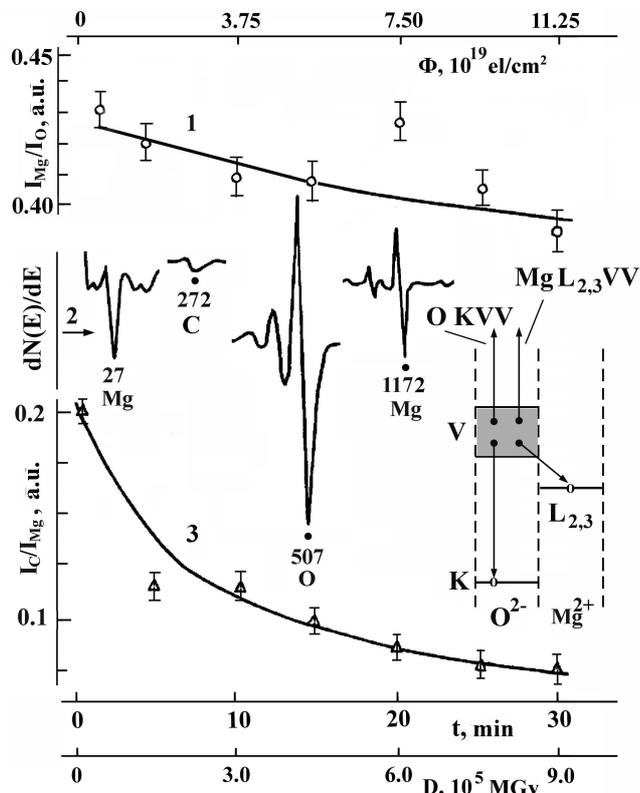


Fig. 2. Change of the surface stoichiometry of MgO in the process of electron irradiation ($j = 10^2 \text{ A/m}^2$, $E = 3 \text{ keV}$): the dependence of the stoichiometry (by the ratio $I_{\text{Mg}(1172)}/I_{\text{O}(507)}$) 1 and the concentration of carbon (by the ratio $I_{\text{C}(272)}/I_{\text{Mg}(1172)}$) on the surface 3 on the dose of the electron irradiation. 2 are the fragments of the Auger-spectra of components of the compound and the Auger-transitions at 27 eV Mg($L_{2,3}VV$) (“skew transitions”) and at 507 eV O(KVV) (“direct transitions”)

chemical elements of MgO, namely $\text{Mg}^{2+}(L_{2,3})$ and $\text{O}^{2-}(V,V)$. That is, the Auger-electrons at the peak Mg(27 eV) are created due to the Auger-transition $L_{2,3}VV$. In this case, the valence band of MgO is formed by the electrons of oxygen. Therefore, the ratio $I_{\text{Mg}(27)}/I_{\text{O}(507)}$ has no real content, since the intensity of the Auger-peak $I_{\text{Mg}(27)}$ is related to magnesium and oxygen. The results of calculations of the relative surface concentrations of MgO are given in Table 1, and those with regard for carbon as the main contaminant of the cleavage surfaces are shown in Table 2. The curves of the relative changes in the stoichiometry of the surface of a crystal of MgO under the irradiation defined as the ratios of the peak-peak amplitudes of the relevant chemical elements, $I_{\text{Mg}(1172)}/I_{\text{O}(507)}$ and $I_{\text{C}(272)}/I_{\text{Mg}(1172)}$, are displayed in Fig. 2 (curves 1 and 3) and in Table 2. It is worth to note that the analysis of the surface stoichiometry by the ratio of the peak-peak amplitudes of the relevant chemical elements does not consider the factors of the element sensitivity of AES, like upon the calculation of their relative concentrations on the surface by the method of pure standards with matrix corrections (see Table 2).

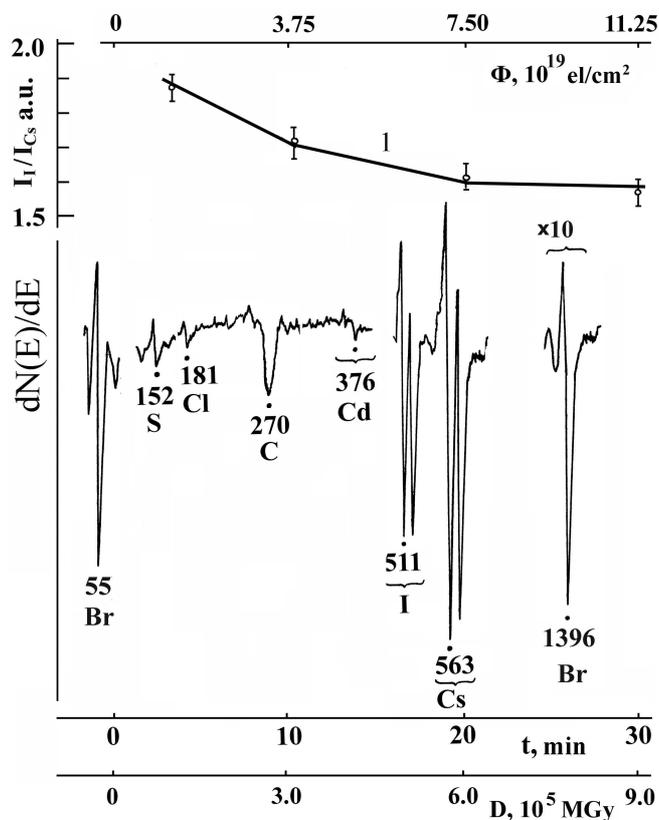


Fig. 3. Change of the surface stoichiometry of thin layers of the solid solution of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$ in the process of electron irradiation ($j = 10^2 \text{ A/m}^2$, $E = 3 \text{ keV}$): 1 — the dependence of the surface stoichiometry (by the ratio $I_{\text{I}(511)}/I_{\text{Cs}(563)}$) on the dose of the electron irradiation; the fragments of the Auger-spectra of components of the compound and extraneous contaminants (S, Cl, and C)

metry by the ratio of the peak-peak amplitudes of the relevant chemical elements does not consider the factors of the element sensitivity of AES, like upon the calculation of their relative concentrations on the surface by the method of pure standards with matrix corrections (see Table 2).

Table 1. Quantitative Auger-analysis of the surface stoichiometry of a crystal of MgO by the method of pure standards with matrix corrections

Irradiation time, min	Rel. concentr. of components of the surface of MgO, %	
	Mg(1172 eV)	O(507 eV)
0–3.3	62	38
5	61	39
10	61	39
15	61	39
20	62	38
25	61	39
30	60	40

Table 2. Quantitative Auger-analysis of the surface stoichiometry of a crystal of MgO by the method of pure standards with matrix corrections with regard for a noncontrolled extraneous contamination

Irradiation time, min	Rel. concentr. of components of the surface of MgO with contaminants, %			Peak-peak amplitudes of chemical elements, rel. units				Ratios of the peak-peak amplitudes of chemical elements		
	Mg (1172 eV)	O (507 eV)	C (272 eV)	Mg (27 eV)	Mg (1172 eV)	O (507 eV)	C (272 eV)	$I_{\text{Mg}(1172)}/I_{\text{O}(507)}$	$I_{\text{C}(272)}/I_{\text{Mg}(1172)}$	$I_{\text{C}(272)}/I_{\text{O}(507)}$
0–3.3	53	33	14	15.5	22.5	59.5	5	0.43	0.2	0.084
5	60	38	2	19	28	66.5	3	0.42	0.11	0.045
10	56	36	8	19.5	28	68	3	0.41	0.11	0.044
15	57	37	6	20	29	70	2.5	0.41	0.09	0.036
20	58	36	6	21.5	30.5	71.5	2.5	0.43	0.08	0.035
25	58	37	5	22	29.5	72	2	0.41	0.07	0.027
30	57	38	5	20.5	29	73	2	0.40	0.07	0.027

Table 3. Quantitative Auger-analysis of electron-stimulated changes of the surface stoichiometry of thin layers of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$ without regard for the concentrations of contaminants

Irradiation time, min	Rel. concentr. of components of the surface of the solid solution of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$, %			
	Cs(563 eV)	I(511 eV)	Br(1396 eV)	Cd(376 eV)
0–3.3	32	60	7.2	0.8
10	34	58	6.8	1.2
20	35	57	6.6	1.4
30	35.5	56.5	6.6	1.4

In the process of electron irradiation, the cleavage surface stoichiometry of the crystal of MgO varies slightly as a function of the dose, which testifies to the significant radiation resistance of this dielectric and its films derived by various methods. However, we observed some increase in the concentration of the oxygen component on the surface, which can be caused by the great coefficients of radiation-stimulated diffusion of nonstoichiometric, weakly bound oxygen and its more rapid diffusion to the surface from the near-surface layers, than that of Mg. In this case, the concentration of carbon as the main extraneous contaminating impurity on the surface of MgO is sharply decreased with increase in the radiation dose, which is a result of the electron-stimulated diffusion and the localization of carbon in deeper near-surface layers of the compound.

By AES, we studied the change in the surface stoichiometry of thin films of the solid solutions of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$ after their contact with air and under the electron irradiation. In the studies of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$ by AES, the parameters of the electron beam were as follows: $j = 10^2 \text{ A/m}^2$ and $E = 3 \text{ keV}$. In this case, the electron beam probing the surface induced the changes in its stoichiometry. The surface stoichiometry of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$ is sharply changed with increase in the dose of electron irradiation to the side of the deficiency of halogen components (Fig. 3), which can be caused by

the destruction of the surface with respect to iodine and bromine and by their intense evolution in vacuum. The results of studies displayed in Table 3 (in the calculations of the relative concentrations of the components, we did not consider the admixtures of extraneous contaminants S, Cl, and C) allow us to conclude that the mechanisms of the enrichment of a surface by Cs and the evolution of iodine are the same as those in CsI [10]. But we failed to register the separation of the metallic phase of Cs in $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$, as it was performed for CsI [10]. The increase in the concentration of Cd with the radiation dose is possibly caused by its migration to the surface due to the radiation-induced shaking of the near-surface layer. In Fig. 3, we present both the dependence of the stoichiometry of ($I_{\text{I}(511)}/I_{\text{Cs}(563)}$) on the radiation dose and the fragments of the Auger-peaks of components of the compound and the main “technological” admixtures.

In the process of irradiation of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$, we observed a remarkable increase in the concentrations of Cs and Cd on the surface as a result of both the possible destruction of the compound with respect to halide components (I and Br) and the possible diffusion of the excessive component of Cd from the near-surface layers to the surface.

3. Conclusions

In the process of electron irradiation, the surface stoichiometry of MgO varies slightly as a function of the radiation dose, which testifies to the high radiation-resistance of this dielectric. In this case, the concentration of carbon as the main extraneous contaminating impurity on the surface of MgO is sharply decreased with increase in the radiation dose, which is a result of the electron-stimulated diffusion and the localization of carbon in deeper near-surface layers of the compound.

Under the electron irradiation of the solid solution of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$, the concentrations of iodine and bromine are considerably decreased due to the possible electron-stimulated destruction of the material with respect to these components and their evolution in vacuum. Moreover, the concentrations of Cs and Cd on the surface increase as a result of both the above-indicated destruction and the diffusion of these elements to the surface from the near-surface layer.

The electron irradiation of the dielectrics under study leads to both the creation of fundamental radiation-induced defects (in the case of $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$) and the transformation of defects of the impurity nature (MgO), which is manifested in the relaxation spectra of TSEE.

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КІЛЬКІСНА СПЕКТРОСКОПІЯ ЕЛЕКТРОННО-СТИМУЛЬОВАНИХ ПРОЦЕСІВ НА ПОВЕРХНІ ШИРОКОЗОННИХ ДІЕЛЕКТРИЧНИХ МАТЕРІАЛІВ

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Резюме

Наведено результати дослідження електронно-стимульованих процесів на поверхні діелектричних плівок MgO та $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$. Результати кількісної оже-електронної спектроскопії (ОЕС) для плівок порівнюються з такими ж, отриманими для монокристалів MgO та $\text{CsI}_x\text{Br}_{1-x}(\text{Cd})$. Методами термостимульованої екзоелектронної емісії (ТСЕЕ) виявлено електронно-релаксаційні, а методами кількісної ОЕС — електронно-стимульовані дифузійні та деструкційні процеси на поверхні і у приповерхневому шарі діелектричних кристалів і плівок, які приводять до змін стехіометрії поверхні при електронному опроміненні.