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ON THE FORMATION OF EXCITED YTTRIUM PARTICLES UNDER ION BOMBARDMENT OF YTTRIUM AND YTTRIUM ALUMINUM GARNET

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Emission spectra of excited yttrium particles ejected from the surface of the yttrium metal and yttrium aluminum garnet (YAG) at Ar^+ ions are studied. The efficiency of yttrium particles excitation defined from experimental data. The assumption is made that the difference in the excitation efficiency for yttrium atoms and ions is due to the different contribution of processes of formation of the excited atoms or ions ejected from solids at the ion bombardment of garnet and metal.

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INTRODUCTION

Ion bombardment of solids accompanied with a number of secondary emission processes, according to one of which excited particles flies off from a target surface with subsequent photon emission. This phenomenon is called ion photon emission (IPE) [1]. In studying the main emission parameters of particles flying off a surface, it is possible to acquire additional information on processes leading to excited particle knocking out, because in this case not only the type of flying off particles, but its state (in particular, state of excitation) can be determined.

Yttrium aluminum garnet ($Y_3Al_5O_{12}$) or YAG is the most important solid-state laser host material. YAG is one of the most creep resistant oxide and has important applications in high-temperature ceramic components. So, due to excusive optical, mechanical and thermal characteristics it is widely technical adopted in different areas of electronics, optoelectronics and optics [2]. Therefore, investigations of the physics-chemical properties of these materials, particularly, the response to ion irradiation and ion-simulated emission are very important.

In this work done comparison of the main parameters of IPE of metallic yttrium (Y) and yttrium aluminum garnet (YAG) for clarifying processes stimulating the escape of excited atoms and ions from these targets at ion bombardment.

EXPERIMENTAL DETAILS

Experiments were provided at the experimental installation using a mass separated 20 keV Ar^+ ion beam with current density of 15…20 μA·cm^{-2}.

The radiation of emitted by excited particles registered and analyzed by a photoelectrical system in mode of photon counting. The optical axis of monochromator was in such a direction to the target surface that emission only from the flying-off particles was registered. The emission spectra investigated in the wave range of 250…800 nm. The experimental details described elsewhere [3, 4].

As shown earlier [4, 5] the spectral composition of radiation from YAG at the bombardment by Ar^+ ions includes some aluminum lines and rich emission atomic (Y I) and ionic (Y II) yttrium spectra. Therefore, only the radiation of yttrium atoms and ions is compared for target Y and YAG.

One of the main parameters of the IPE is the quantum yield of radiation due to the transitions from the initial *i*-th state to a final *k*-th state ($i \to k$) which defined as the number of emitted photons related to one incident ion (γ_{ik}). This value is determined directly from experimental data according to the formula:

$$\gamma_{ik} = \Sigma N_{ik} / N^+, \quad (1)$$

where ΣN_{ik} is the total number of photons from the $i \to k$ transitions and N^+ is the number of incident ions. Neglecting any possible influence of cascade transition from higher levels to the initial *i*-th level, the number of particles in the i-th state (n_i) sputtered by one ion is defined by the relation:

$$n_i = \gamma_{ik} (b_{ik})^{-1}, \quad (2)$$

where b_{ik} is the relative probability of the $i \to k$ transition, $b_{ik} = A_{ik}(\Sigma A_{if})^{-1} = A_{ik}\tau_i$, where A_{ik} is the probability of the $i \to k$ transition, ΣA_{if} – is the probability of all possible transitions from level i to f-th different states, τ_i is the lifetime of the i-th level. According to [6] the population n_i of the i-th excited level is defined by two parameters: the statistical weight g_i and the state excitation energy E_i:

$$n_i = g_i \, exp\,(-E_i / kT), \quad (3)$$

i.e. determined by spectroscopic parameter g_i and the excitation state energy E_i.

In this context, it is expedient to introduce the concept of the excitation efficiency σ_i, which characterizes the transition of a particle to the state with the energy E_i under the action of a single ion:

$$\sigma_i(E_i) = n_i / g_i. \quad (4)$$

Taking into account (2) we can express dependency $\sigma_i(E_i)$ in terms of experimentally determined values of γ_{ik}:

$$\sigma_i(E_i) = \gamma_{ik} (g_i A_{ik} \tau_i)^{-1}. \quad (5)$$

EXPERIMENTAL RESULTS

In this work, the emission spectra of excited particles at ion bombardment of the studied targets (polycrystalline Y and single crystal of yttrium aluminum garnet YAG) were analyzed; the lines of the Y I and Y II spectra with the intensities at least twice higher the background level were selected. Table 1 shows the

wavelengths of the selected lines (λ) for the atomic spectrum of yttrium (Y I) and the spectroscopic parameters of the upper level of the transition leading to the emission of the studied lines (electronic configuration, the term and the excitation energy E^*, the transition probability A and the lifetime of the level τ). In addition, the table shows the intensities ($I = \gamma hc/\lambda$) of these lines in the arc spectra [7] and the quantum yield (γ) determined for the targets studied in the work.

The same parameters for the lines of the yttrium ion spectrum (Y II) are shown in Table 2.

As followed from the Tables 1 and 2, although the spectral composition of the radiation for Y and YAG is the same, but the intensity distribution in the spectra has a number of differences.

Table 1

Spectroscopic parameters of the Y I spectrum lines

λ, nm [7]	El. conf. [8]	Term [8]	E^*, eV [7]	A_{ik}, 10^8 s^{-1} [8]	τ_i, 10^{-8} s	I [7]	γ_{ik}, 10^{-6} ph/i (Y)	γ_{ik}, 10^{-6} ph/i (YAG)
362.09	4d5s(^{1}D)5p	x ^{2}P°$_{3/2}$	3.49	2.34	0.39	550	19.55	20.5
408.37	4d5s(^{3}D)5p	y ^{2}P°$_{3/2}$	3.03	0.25	1.79	200	29.39	28.9
410.23	4d5s(^{1}D)5p	y ^{2}F°$_{7/2}$	3.08	1.27	0.79	1000	42.91	42.9
412.83	4d5s(^{1}D)5p	y ^{2}D°$_{5/2}$	3.06	1.56	0.6	900	29.83	29.8
414.28	4d5s(^{1}D)5p	y ^{2}D°$_{3/2}$	2.99	1.59	0.53	750	21.80	21.2
464.37	4d5s(^{3}D)5p	z ^{2}F°$_{5/2}$	2.67	0.18	4.65	170	63.84	48.5
467.48	4d5s(^{3}D)5p	z ^{2}F°$_{7/2}$	2.72	0.13	7.52	170	77.20	68.8
476.09	4d5s(^{3}D)5p	z ^{2}F°$_{5/2}$	2.67	0.035	4.65	34	19.63	11.0
552.75	4d^2(^{3}F)5p	z ^{4}G°$_{9/2}$	3.64	0.54	1.67	50	45.24	37.4
563.01	4d^2(^{3}F)5p	z ^{4}G°$_{5/2}$	3.55	0.45	1.83	38	31.16	25.1
570.67	4d5s(^{3}D)6s	e ^{4}D$_{7/2}$	4.18	0.3	1.5	11	9.50	10.6
619.17	4d5s(^{3}D)5p	z ^{2}D°$_{3/2}$	2.00	0.046	20.3	80	42.20	70.5
643.50	4d5s(^{3}D)5p	z ^{2}D°$_{5/2}$	1.99	0.041	21.36	70	196.10	261.2
653.86	4d^2(^{3}F)5p	z ^{2}G°$_{9/2}$	4.19	0.149	2.03	6	10.12	11.9

Table 2

Spectroscopic parameters of the Y II spectrum lines

λ, nm [7]	El. conf. [8]	Term [8]	E^*, eV [7]	A_{ik}, 10^8 s^{-1} [8]	τ_i, 10^{-8} s	I [7]	γ_{ik}, 10^{-6} ph/i (Y)	γ_{ik}, 10^{-6} ph/i (YAG)
324.22	4d5p	y ^{3}P°$_2$	4.01	2.03	0.36	800	0.71	2.15
361.10	4d5p	z ^{3}D°$_2$	3.56	1.04	0.43	1000	0.8	3.2
363.31	4d5p	z ^{1}P°$_1$	3.41	1.3	0.53	1000	0.7	3.4
371.02	4d5p	z ^{3}F°$_4$	3.52	1.54	0.57	1500	2.8	12.1
377.44	4d5p	z ^{3}F°$_3$	3.41	1.1	0.63	1200	2.6	8.7
378.87	4d5p	z ^{3}F°$_2$	3.37	0.8	0.65	850	1.2	4.7
383.28	4d5p	z ^{3}F°$_3$	3.41	0.295	0.63	460	0.9	2.4
430.96	5s5p	z ^{3}P°$_2$	3.05	0.128	5.69	280	3.8	10.7
437.49	4d5p	z ^{1}D°$_2$	3.24	1.0	0.63	1200	3.0	9.2
439.80	5s5p	z ^{3}P°$_1$	2.95	0.1151	5.0	180	3.4	6.9
478.65	4d5p	z ^{3}D°$_3$	3.62	0.021	0.44	13	3.8	4.8
482.33	4d5p	z ^{3}D°$_2$	3.56	0.044	0.43	16	6.5	6.6
488.36	4d5p	z ^{3}D°$_3$	3.62	0.47	0.44	160	6.4	6.4
490.01	4d5p	z ^{3}D°$_2$	3.56	0.45	0.43	95	5.9	6.2
512.32	4d5p	z ^{1}P°$_1$	3.41	0.13	0.53	30	7.9	11.7

An increase in the quantum yield for the metal in comparison with YAG is observed for the lines of the Y I spectrum emitted by yttrium atoms in the states z ^{2}F° and z ^{4}G°. For z ^{2}D° levels, having the lowest excitation energy, the picture reversed.

It is interesting to compare the quantum yield for a group of closely located lines (λλ 408.37, 410.23, 412.83, and 414.28 nm) with the intensity of these lines given in [7]. It can be seen that the 408.37 nm line has an anomalously high quantum yield for both metal and YAG compared to neighboring lines, although in the arc spectrum it is 3-5 times weaker than its neighbors.

It should be noted that the quantum yield of most lines of the ion yttrium spectrum (Y II) is significantly higher (by a factor of 2-3) for YAG than that for the metal. The exception is a group of lines (λλ 478.65, 482.33, 488.36, 490.01, and 512.32 nm), that have an anomalously high quantum yields for both yttrium and YAG. Moreover, this group of lines is also anomalously intense in comparison with the arc spectrum of yttrium [7].

At using the quantum yields of radiation for the lines of the Y I and Y II spectra and the corresponding spectroscopic parameters given in Tables 1 and 2, the level excitation efficiency (σ) of a number of excited states of yttrium atoms and ions was determined according to the formula (5). These values lie in the range $(0.1\ldots100)\cdot10^{-6}$, and since further only the relative change of the excitation efficiency on the excitation energy will be considered, only numerical values were used to plot the dependence $ln\ \sigma = f(E^*)$.

The dependence $ln\ \sigma = f(E^*)$ for lines emitted by excited yttrium atoms (Y I) at ion bombardment of metal (*a*) and YAG (*b*) is shown in the Fig. 1. One can see the similarity of these dependences for two targets.

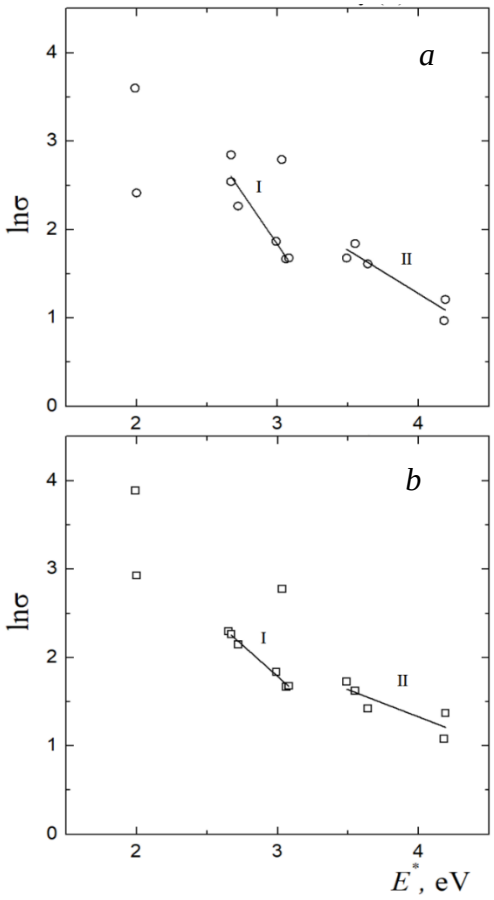

Fig. 1. Dependence of the levels excitation efficiency of the studied states of Y atoms on the excitation energy for two targets: Y (a); YAG (b)

Most points can be approximated by two straight line segments: I – points at $E^* < 3$ eV and II – points at $E^* > 3$ eV. Points of the levels with the lowest excitation energy ($E^* = 1.99$ and 2 eV) and at $E^* = 3.03$ eV (the level, the transition from which leads to the emission of photons with a wavelength of $\lambda = 408.37$ nm) are located apart.

The dependence $ln\ \sigma = f(E^*)$ for lines emitted by excited yttrium ions (Y II) at ion bombardment of metal (a) and YAG (b) is shown in the Fig. 2. One can see that the efficiency of excitation of the corresponding levels is approximately 2.5 times higher for garnet than for metal. However, in both cases, the points can be approximated by a straight line. The exception is the group of points that clearly fall out of the dependence $ln\ \sigma = f(E^*)$ for both metal (see Fig. 2,a) and yttrium aluminum garnet (see Fig. 2,b).

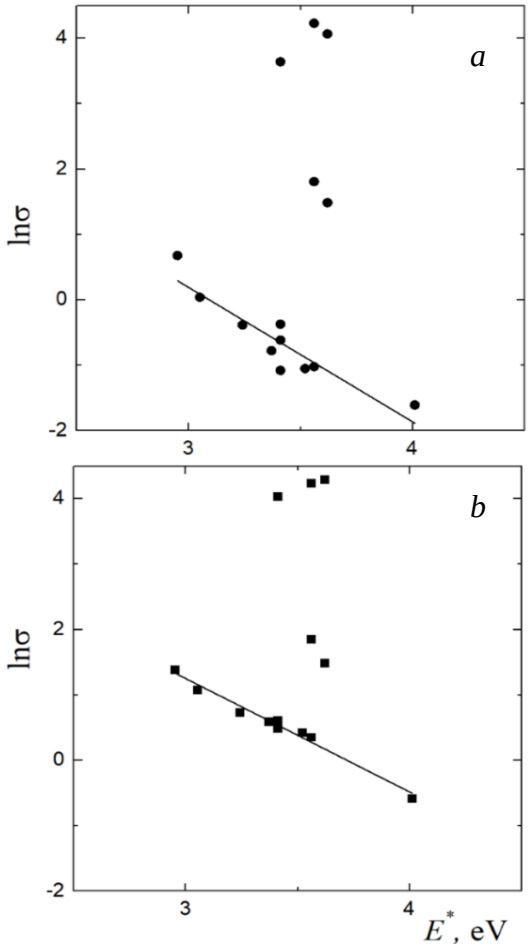

Fig. 2. Dependence of the levels excitation efficiency of the studied states of Y ions on the excitation energy for two targets: Y (a); YAG (b)

The velocity of the knocked-out excited yttrium atoms and ions was estimated from an analysis of the spatial distributions of radiation ($ln\ \sigma = f(l)$), (l is the distance from the target surface) of the most intense lines of the spectra Y I and Y II according to [9]. It turned out that for the lines of the spectrum Y I, due to transitions from the states z ^{2}F°, y ^{2}D°, and y ^{2}F°, the dependence $ln\ \sigma = f(l)$ can be approximated by two straight line segments with different slopes, that meant a two-velocity composition of flying off the surface excited yttrium atoms in these states. The calculations showed that the group of "slow" particles (I) had the kinetic energy (E_k) of the order of 100…500 eV. Moreover, for metal $E_k(m)$ ~100 eV, and for YAG the kinetic energy of the group of "slow" particles is higher, it is about 400…500 eV. For "fast" particles (II) knocked out from both types of targets, the values of the kinetic energy are in the range of 1000 ... 3000 eV. For lines in the Y I spectrum with an excitation energy above 3 eV and for all lines in the Y II spectrum, the dependence $ln\ \sigma = f(l)$ can be approximated by a single straight-line segment. The value of the kinetic energy determined from these dependences are of the order of several kiloelectronvolt for both yttrium target and YAG.

DISCUSSIONS

To understand the mechanism of formation of sputtered excited yttrium particles, it is necessary to answer two basic questions: 1) how the kinetic energy is transferred from the primary ion to the secondary particle knocked out of the solid; 2) what processes result in the secondary particle excitation. One of the possible classifications of ion sputtering processes according to the time of their duration presented in [10]. If we assume that the primary ion falls on the target at the moment $t = 0$, then in the interval $10^{-15} \le t \le 10^{-14}$ s fast collisional processes, the so-called multiple collisions, take place. Slow processes, so-called collision cascades, follow in the interval $10^{-14} \le t \le 10^{-12}$ s. Times $10^{-12} \le t \le 10^{-10}$ s correspond to fast thermal processes of atoms emission as a result of their evaporation from bombarded area the surface called "a thermal spike". Slow thermal processes at $t \ge 10^{-10}$ s, include, for example, the evaporation of alkali metal halogens after their neutralization by diffusing defects. It should be note that thermal processes are occurring only at certain parameters of the ion beam and not in all materials. So the formation of excited sputtered particles during the bombardment of the solids surface by medium-energy ions mainly occurs in the first two processes: 1) multiple collisions of the bombarding particle with the atoms of the solid surface and 2) collision cascades.

As to the processes of excitation of sputtered particles, the currently existing theoretical models [10 - 13] can be conventionally divided into four types. 1) Collision (kinetic) models, according to which the excitation of a sputtered particle is a result of its collision with an atom, ion, or electron both on the surface of a solid and above it. 2) Electron-exchange models that suppose the excitation of the knocked-out particle due to the perturbing influence of the solid-vacuum boundary on the electron shells of the knocked-out atom or ion. 3) Molecular models, considering the excitation of molecules that form an irradiated solid or are formed on the target surface during the adsorption of chemically active elements (in particular, oxygen) with their subsequent dissociation. The dissociation of excited molecules on the surface or outside it is the main reason formation of atoms, ions or clusters that make up the molecule in excited state. 4) Thermodynamic models based on the assumption of the formation of plasma in local thermodynamic equilibrium (LTE) at the site of ion impact (under, on or above the surface), which leads to the exit from this region of a stream of atoms (including excited ones), ions and electrons. For plasma in LTE, there should be an equality of effective temperatures for different types of plasma particles, that does not correspond to the results of studies of excited particle radiation; as a result of that the use of the concept of LTE at the site of ion impact is not always rational. At the same time, a number of authors [14, 15] propose to use different models simultaneously, thus allowing the simultaneity of various mechanisms at the formation of excited particles. Summarizing the above, we can present a simplified scheme, noting the most pronounced processes leading to the formation of excited atoms and ions of yttrium at the ion bombardment of Y and YAG.

When a primary ion interacts with a solid in the region $l \le 0$ (that is, inside the solid or on its surface), processes leading to the departure (knocking out) of particles occur. These are multiple collisions of an incident ion with one or several target particles and the development of a cascade of linear collisions within a solid. The process of multiple collisions can be considered as a collision of a primary ion with a surface particle. The flying-off particle in these collisions can be either a particle of target or a beam particle (at bombardment by light ions). The kinetic energy of such particles is comparable to the energy of the primary beam ion. During the development of cascades of linear collisions, the primary ion, penetrating into a solid, transfers momentum to its particles. They, in turn, transfer the received momentum to other particles. As a result of such transfer, cascades of collisions occur, which transfer momentum to the surface particles of a solid in a relay-race way. If this impulse has the appropriate magnitude and direction, then the surface particle will be knocked into vacuum. The most probable energy of such knocked-out particles is on the several tens of electronvolt. The presence of two velocity groups of knocked-out excited yttrium atoms (with kinetic energies of $100 \dots 500$ eV and several kiloelectronvolt) indicates the simultaneous action of two above named knock out mechanisms.

When the bond with the solid is broken ($0 < l < l_0$, where l_0 is the order of several atomic sizes), the excited state of the flying-off particle is formed. In multiple collisions, the excited state forms when the joint electron cloud of a pair of colliding particles is separating. Therefore, it is likely that the dependence $ln\ \sigma = f(E^*)$ for highly excited states of the yttrium atom is similar for metal and garnet. The same can be said about the ionic lines of yttrium. During the development of a cascade of collisions, an excited state of flying off particle forms in the result of electron exchange between the solid and the particle; the probability of this process is determined, in particular, by the distribution of the valence electrons density, which differs significantly for yttrium metal and yttrium aluminum garnet. Yttrium work function $\varphi = 3.3$ eV [12], and the YAG band gap, according to [16], is about 5 eV. Therefore, the dependence $ln\ \sigma = f(E^*)$ for the states of the yttrium atom with low excitation energies ($E^* \le 3$ eV) is different (different slopes of segments (I)) for the studied targets. With further removal of the flying off particle ($l_0 \le l$), its state may change due to the processes of resonant neutralization and resonant ionization. The probability (P) of this processes is determined by the type of process and the velocity of the flying off excited particle $P = exp(-A/av_\perp)$, where A and a are constants depending on the process under consideration and the type of interacting pair (flying off particle – solid), $v_\perp$ is the normal component of the flying particle velocity. Let us consider how the action of these processes manifests itself in the formation of excited yttrium atoms and ions.

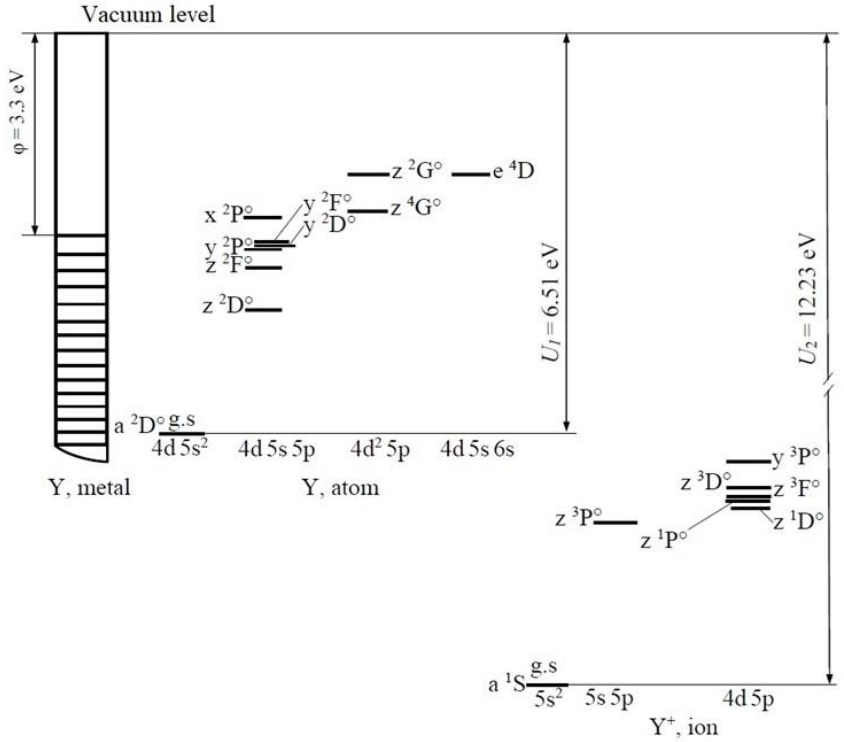

Fig. 3. Position of energy levels of excited states of yttrium atoms and ions relative to the band structure of yttrium metal

The layout of the levels of the excited states of atom and ion of yttrium and the band structure of the metal (Y) with respect to the vacuum level, is shown in Fig. 3. The lines λλ 464.37, 467.48, and 476.09 nm (Y I) are due to the emission of yttrium atoms in the state z ^{2}F° that have low kinetic energy. As is evident from Fig. 3, the levels of that excited state are located opposite the levels of the filled part of the conduction band of the metal. Consequently, the probability of losing excitation by slow excited atoms in that state by the process of resonant ionization is small. Moreover, some of the slow ions may lose its charge due to the transition of electron from filled part of the conduction band of the metal to resonantly located levels of the excited atom. For excited atoms which levels located resonantly to the free part of the conduction band of the metal, process of the resonant ionization for particles with a low speed occurs with a high probability; this explains the medium and high values of the kinetic energy of yttrium atoms in states with $E^* > 3$ eV. From analysis of the position of the excited states levels of the yttrium ion relative to the band structure of the metal, it is evident that the probability of resonant ionization (without emission of a photon) for them is small. Nevertheless, lines emitted only by ions with high (the order of the primary beam energy) kinetic energy are observed in the work. This suggests that the excited state of ions (as noted above) forms in the process of multiple collisions. Thus, we can say that the efficiency of excitation of most levels (except for the cases considered below) is determined by the excitation energy of the level and its position relative to the distribution density of valence electrons in the solid.

It should be especially noted in Figs. 2 and 3 the position of several points that clearly fall out of the graphs of the dependence $ln\ \sigma = f(E^*)$ for both Y and YAG. For excited yttrium atoms, these are the points for the levels of the z ^{2}D state. First, this is the lowest excited state, whose the level population is strongly affected by cascade transitions from higher-lying excited states [8]. Secondly, they have a long lifetime, due to which there may not be a full collection of radiation when determining the values of the quantum yield. It is very difficult to take into account correctly the influence of these processes on the population of the levels of the indicated state. That probably explains the special values of the excitation efficiency of the state z ^{2}D in Figs. 2 and 3. For excited yttrium ions, there are also several (5) points that clearly do not lie on the $ln\ \sigma = f(E^*)$ dependence. A feature of the lines λλ 478.65, 482.33, 488.36, 490.01, and 512.32 nm is their location in the spectral region of the emission of the blue-green system of the YO molecule, the transition $^2\Sigma \rightarrow {}^2\Sigma_{main\ state}$. Although the contribution of the radiation from the molecular band was taken into account (subtracted) in the calculation of the quantum yield, the influence of the band edges on the intensity of these lines is probably remained.

Finally, it is necessary to note the anomalously high excitation efficiency of the y ^{2}P°$_{3/2}$ (Y I) level, the transition from which is accompanied emission of line λ 408.37 nm. Firstly, the probability of cascade repopulation of this level is low; secondly, the lifetime of this level is comparable to the lifetimes for most levels of other excited states [8]. However, during ion bombardment both the metal and YAG, the effective population of this level is very high, so that the corresponding point on the dependence $ln\ \sigma = f(E^*)$ is located higher than the points of closely spaced levels y ^{2}F°$_{7/2}$ and y ^{2}D°$_{5/2}$.

Probably, the formation of this excited state can be related to the collapse of the metastable state of a complex compound (metal atom-oxygen atom), which is knocked out from the solid surface during ion bombardment.

Previously, in studies of the regularities of IPE during ion bombardment of complex compounds [17, 1, 18], the possibility of the excited particles formation due to the breakdown of a molecule in a metastable state was noted. In our case, both for the metal target (Y) and for YAG, the emission spectra of knocked-out particles contains bands of the blue-green system of the YO molecule. This indicates on the presence of adsorbed oxygen on the metal surface. In YAG, which has the chemical formula $Y_3Al_5O_{12}$, five aluminum ions occupy a position in two octahedra (*VI*) and three tetrahedra (*IV*), yttrium ions occupy a dodecahedral (*VII*) sublattice and are surrounded by eight oxygen ions. So, their structural formula can be written as $\{Y\}^{VIII}_3\ \{Al\}^{VI}_2\ \{Al\}^{IV}_3\ O_{12}$. Therefore, during ion bombardment of both the metal and YAG, it is possible to knock out the YO molecule in a metastable state, at the decay of which yttrium atoms are formed in a certain state and oxygen.

CONCLUSIONS

The comparison of main parameters of IPE during bombarding yttrium metal (Y) and yttrium aluminum garnet ($Y_3Al_5O_{12}$) by 20 keV Ar^+ ions was done to clear the mechanisms of excited yttrium atoms and ions formation depending on the physicochemical parameters of the solid. For the studied targets, the emission spectra of sputtered excited atoms and ions yttrium analyzed and the dependences of the excitation efficiencies of levels on the excitation energy for the corresponding states were determined. It was shown that as a result of collision processes (multiple or cascade) of an incident ion with solid particles, both atomic yttrium particles and metastable complexes of the $(Y_mO_n)^{k*}$ type are knocked out. In the case of multiple collisions of an incident ion with target particles, the ejected particle acquires significant kinetic energy (several keV), and the excited state is formed when the common electrons of particles are separated. The development of a cascade of collisions in a solid leads to the emission of particles with a low kinetic energy (up to several hundreds of eV). Since in this case the speed of the flying particle ($\sim 10^5 \ldots 10^6$ cm·s^{-1}) is less than the speed of the Bohr electron ($\sim 10^8$ cm·s^{-1}), it can be assumed that the excited state of the flying particles is formed during the adiabatic decay of the solid-flying atom system. The formation of the excited state of the flying particle is completed when it moved away from the surface at a distance of the order of atomic dimensions. With further removal of the particle, its state may change due to the processes of nonradiative loss of excitation as resonant ionization or Auger deexcitation. The probability of each of these processes is determined by the position of the excited state level relative to the conduction band of the solid and the velocity of the flying-off particle.

Finally, for a flying off particle in a state with a low excitation energy, there was a high probability of an additional population of the state under study in the result of cascade transitions from the overlying states to the state under study. During ion bombardment of complex targets, which include a chemically active element (for example, oxygen) or its adsorption on the target surface, the knocked-off metastable excited complex (metal atom-oxygen atom) could break up on an excited atom of yttrium and oxygen.

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УТВОРЕННЯ ЗБУДЖЕНИХ ЧАСТИНОК ІТРІЮ ПРИ ІОННОМУ БОМБАРДУВАННІ ІТРІЮ ТА ІТРІЄВО-АЛЮМІНІЄВОГО ГРАНАТА

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Досліджено спектри випромінювання збуджених частинок ітрію, розпилених з поверхні металевого ітрію та ітрій-алюмінієвого граната (YAG) іонами Ar^+. За експериментальними даними визначена ефективність збудження частинок ітрію. Зроблено припущення, що різниця в ефективності збудження атомів та іонів ітрію зумовлена різним внеском процесів утворення збуджених атомів чи іонів, розпилених з твердих тіл при іонному бомбардуванні граната та металу.