# ACOUSTIC EMISSION ON THE RELAXATION OF LOCAL THERMOMECHANICAL STRESSES IN THE PROCESS OF DEGRADATION OF LIGHT-EMITTING HETEROSTRUCTURES ON THE BASIS OF InGaN AND GaAsP

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We present the results of of studies of the correlation of acoustic emission (AE) and reversible and irreversible changes of electrophysical characteristics of the light-emitting heterostructures on the basis of InGaN and GaAsP in the process of their degradation on the passage of the forward current with a critical density. It is established that the process of local rearrangement of a defective structure on the passage of a current, which is accompanied by AE, has thermoactivation character: with increase in the temperature, the AE occurence threshold decreases, and, at the same time, the number of active sources of AE grows. With decrease in the temperature, the AE occurence threshold approaches the destruction threshold. In this case, the processes of natural ageing considerable increase the thresholds of the AE occurence and the destruction of a structure.

## 1. Introduction

Multilayer light-emitting heterostructures on the basis of $A^3B^5$ compounds are referred to low-dimensional structures [1], whereas the same heterostructures with quantum wells – to nanodimensional ones [1, 2]. One of the peculiarities of such structures is the significant influence of the surfaces and interfaces of epitaxial layers on their luminescent and electric characteristics due to naturally created local mechanical stresses (LMS) in a considerable part of the total volume of a heterostructure, namely in the near-surface layers of each of the epitaxial layers.

The creation of both LMS in epitaxial layers, in the volume of the substrate, and in the region of metal-heterostructure contacts [3] and local inhomogeneous thermomechanical stresses (TMS) on the passage of a current [4–6] is caused by a number of reasons, in particular by the differences of the moduli of elasticity, the coefficients of thermal expansion $\alpha_i$, lattice constants $a_i$, and the stoichiometric composition of epitaxial layers [1–6].

On the passage of a forward current, extreme TMS arise because of the inhomogeneity of a distribution of the current density $J$ in the heterojunctions of light-emitting structures [4–6, 7]. Then the action of an additional pressure of at least $10^7$ Pa in $A^3B^5$ crystals can form defects of various sizes [4,5], which leads, in particular, to the fast degradation of the quantum yield of electroluminescence (EL) [1, 4, 5, 8–10]. It is also known that the overheating of the active region of structures up to $T_{\rm over}$ (it is commonly supposed that $T_{\rm over} < 100$ K [11, 12]) leads, in particular, to shifts of the maxima of the EL spectrum by several nanometers due to additional TMS [11, 12].

Under certain conditions, this can cause the "wear-out" of the AE sources, i.e. the fast relaxation of separate LMS and a local reconstruction of the structure with the emission of rapidly damped spontaneous chaotic pulse acoustic waves [13–15]. This process known as the acoustic emission of materials [14, 15] can correlate in time with the excessive current-involved and optical noises of $A^3B^5$-based heterostructures [16, 17].

Point defects and their inhomogeneous spatial distribution affect the spectrum, the integral intensity of EL, and the rate of degradation [4, 5, 8–10, 14, 15]. In many aspects, this influence depends on the temperature $T$, which is determined, in particular, by the forward current of a junction. However, the separately taken point defects are not considered as potential independent sources of AE due to their extremely low excessive elastic energy (the energy of AE). To the sources of AE, structural defects of higher dimensions or their complexes are referred [14, 15, 18, 19].

It was shown in [13] that, in the $Ga_{0.7}Al_{0.3}As$:Zn,Te/GaAs, $Ga_{0.65}Al_{0.35}As$:Zn, Te/GaAs, $GaAs_{0.15}P_{0.85}$:N, Zn–O/GaP and GaP:N,Zn/GaP structures, the processes of natural ageing decrease the intensity of AE and the total AE and increase the current density $J_{cr}$ related to the AE occurrence by 10–20 times and the working current densities $J$ by 10–50 times. The studies [8, 9] indicate also the connection between the evolution of the spectra of EL, the degradation of current-voltage characteristics (CVC), and the origination of AE.

It follows from [8–10] that the EL spectrum can depend not only on a material, the heterojunction structure, and the relaxed state of point defects which is individual for every structure, but also on a present, in particular nonequilibrium, state of a defective structure of the crystal (the substrate) on the whole and on the acting nonuniform TMS varying in time. In particular, the EL spectra are characterized [8–10, 13] by considerable reversible and irreversible shifts (up to 50 nm) of maxima of the green and red bands of EL which significantly exceed all the shifts available in the literature [1, 4, 5, 12].

The development of optical methods of investigation, recording, and communication indicates that the most promising source of emission is superluminescent heterostructures. But the question about the duration of stable operation, in particular, of those structures which emit in the blue and, especially, ultraviolet ranges remains to be key due to the significant uncontrolled local processes of structural relaxation and defect-forming [3]. For example, for the AlGaN/GaN heterostructures with $\lambda \sim 280$ nm, this time interval is bounded by 100 h. The reason for their superfast destruction is explained sometimes [3] by LMS-induced degradation, in particular via the additional diffusive processes, formation of electrically active defects, metallization of a $p$-contact, etc. With increase in the temperature by $\Delta T \sim 10$ K, the term of their operation reduces by two times [11, 20]. We showed earlier [9, 13] that the registration of the AE damping on the step-by-step increase in $J$ allows one to essentially enhance the working current densities $J$ of heterostructures.

In this connection, the main purpose of the present work is the study of a possible correlation of AE and reversible and irreversible changes of main electrophysical characteristics of the light-diode heterostructures on the basis of semiconducting InGaN and GaAsP compounds in the process of their degradation on the passage of a forward current with critically great density.

## 2. Experiment

The main object of the study was InGaN/GaN structures on a sapphire substrate with an $In_xGa_{1-x}N$-quantum well of 30 Å in width, where the $n$-domains of structures were doped with Si at the concentration $N_d = 3 \times 10^{18}$ cm$^{-3}$, and the $p$-domains were doped with Mg with $N_a = 3 \times 10^{17}$ cm$^{-3}$. The heterojunction area was $400\times400$ $\mu$m$^2$.

In the study of the processes of natural ageing, we used the structures on the basis of compounds $GaAs_{0.15}P_{0.85}$ (with the ageing time $t_{\rm ag} = 3\times10^6 \div 10^7$ s) and the structures $GaAs_{0.15}P_{0.85}$:N, Zn–O/GaP and $Ga_{0.7}Al_{0.3}As$:Zn,Te/GaAs (similar to ones studied in [10, 13]) naturally aged for $t_{\rm ag} \approx 6 \times 10^8$ s ($\sim 20$ yr).

All structures had point contacts with the upper layer and were filled with polymethylmethacrylate, whose contribution to the AE occurrence at electric field strengths up to 300 V/cm and temperatures up to 500 K was excluded by additional studies of AE like in [13].

Signals of AE were registered with a piezoelectric sensor and a specialized AE-device AF-15 in a frequency interval of 200–500 kHz on the total amplification of signals as high as 69–73 dB and were processed like in [8–10, 13, 16].

The studies were carried out at the critically great densities of a forward current $J_i$ up to 460 A/cm$^2$; in this case, the limiting working forward currents of the heterostructures $I_n$ were $10 \div 20$ mA (with the corresponding current densities $J_n = 6 \div 14$ A/cm$^2$). The increase in $J_i$ was performed by steps with their decrease after the AE occurrence threshold by a factor from 1.2 to 2 with the relevant ($2 - 6\times10^2$ s) time delay on each step for both the control over the dynamics of AE and the determination (by the damping of AE) of the time moment of the next step by the method given in [13, 17]. On the rapid (10–300 s) change of $J_i$ without

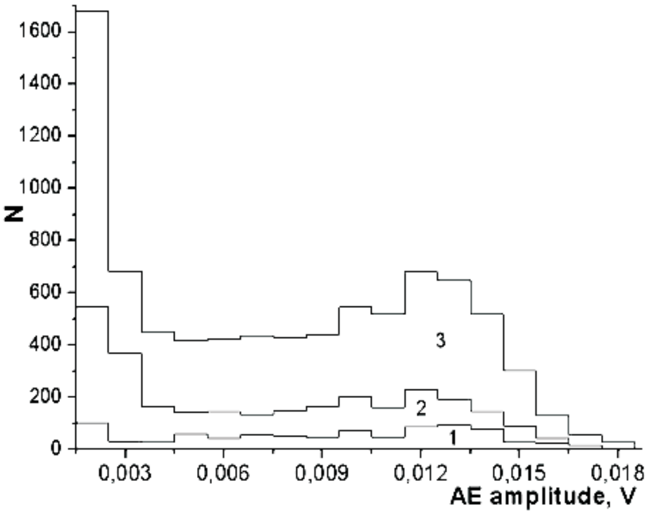


Fig. 1. Histogram of the amplitude distribution of pulses of AE of the InGaN/GaN heterostructure: $J = 200$ A/cm$^2$; *1* – $\tau_n = 300$ s; *2* – $\tau_n = 600$ s; *3* – $\tau_n = 900$ s

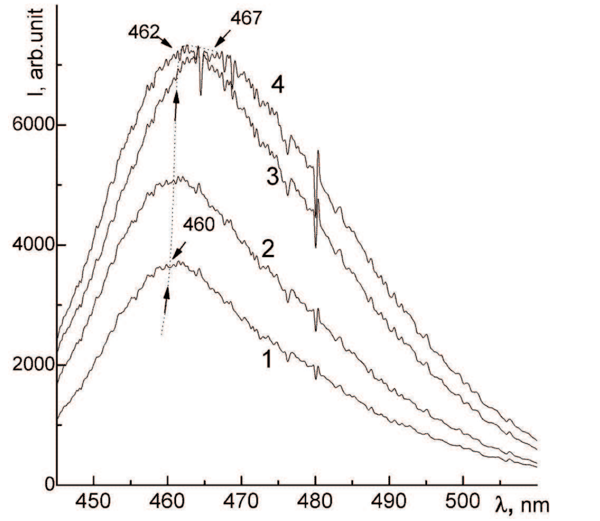


Fig. 2. Evolution of the EL spectrum of the InGaN/GaN structure: *1* – $J = 12$ A/cm$^2$, $U_{\rm forw} = 3.07$ V; *2* – $J = 25$ A/cm$^2$, $U_{\rm forw} = 3.23$ V; *3* – $J = 44$ A/cm$^2$, $U_{\rm forw} = 3.41$ V; *4* – $J = 56$ A/cm$^2$, $U_{\rm forw} = 3.65$ V

control over the dynamics of the damping of AE, all specimens of the control group were destroyed.

## 3. Results

In Fig. 1, we present a typical histogram of the amplitude distribution of signals (ADS) of AE for one of the heterostructures InGaN/GaN studied at $J_i = 200$ A/cm$^2$, which corresponds to the occurence of the intense AE in it which can be classified as discrete [14, 15]. The construction of ADS was performed for various time intervals $\tau_n$ of accumulation of the AE signals from the start of the registration of AE at a given $J_i$. It is seen from Fig. 1 that the ADS of AE is changed. In this case, instead of the exponentially decreasing (theoretically) ADS [14, 15, 18, 19], the growth of $\tau_n$ is accompanied by the formation of a characteristic maximum in the high-energy region of AE signals. The last fact means the activation and the switch-on of a significant number of "one-type" sources of AE which have the same energy of AE and, probably, the same origin [18, 19].

**T a b l e 1. Mean values of the critical currents**

| $t_{\rm ag}$, s | Current strength / Current density | 300–310 K | 280–290 K | 180–200 K | 77 K |
|---|---|---|---|---|---|
| 6×10$^6$ | $I$, mA | 120 | 140 | 170 | 290 |
| | $J$, A/cm$^2$ | 75 | 90 | 110 | 180 |
| 6×10$^8$ | $I$, mA | 190 | 300 | 350 | 500 |
| | $J$, A/cm$^2$ | 120 | 190 | 220 | 310 |

**T a b l e 2. Values of maximum currents**

| $t_{\rm ag}$, s | Current strength / Current density | 280–290 K | 77 K |
|---|---|---|---|
| 6×10$^6$ | $I$, mA | 250–300 | 450–500 |
| | $J$, A/cm$^2$ | 160–190 | 250–280 |
| 6×10$^8$ | $I$, mA | 450–500 | 600–730 |
| | $J$, A/sm$^2$ | 280–310 | 375–460 |

In order to determine the change of critical values of $J_{\rm cr}$ (at which the irreversible increase in the resistance $R_d$ occurs and AE arises) stimulated by the relaxation of internal LMS and TMS, we measured the static CVCs of the heterostructures $Ga_{0.7}Al_{0.3}As$:Zn,Te/GaAs, $GaAs_{0.15}P_{0.85}$:N,Zn–O/GaP, and InGaN/GaN from $J = 0$ to $J \gg J_n$. We used the following modes: without heat removal (300–310 K), with water-involved heat removal (280–290 K), in nitrogen vapors (180–200 K), and under the surface of nitrogen at 77 K (Table 1).

We have established that, in the majority of naturally aged structures with $t_{\rm ag} \approx 6\times10^8$ s on the basis of $GaAs_{0.15}P_{0.85}$ and $Ga_{0.7}Al_{0.3}As$, the greater values of maximum currents $I_{\rm max}$ can be attained, as compared with those in structures with $t_{\rm ag} = 3 \times 10^6 \div 10^7$ s (Table 2). It is worth noting that the current $I_{\rm max}$ are the limiting (destructive) ones for the absolute majority of the heterostructures under study (more than 150) which were fabricated even by different growing technologies such as the liquid-phase and gas-phase epitaxies, the epitaxy from metalloorganic compounds (MOCVD), and their modifications.

In Figs. 2 and 3, we show the evolution of the blue ($B$) band of the EL spectrum of the InGaN/GaN

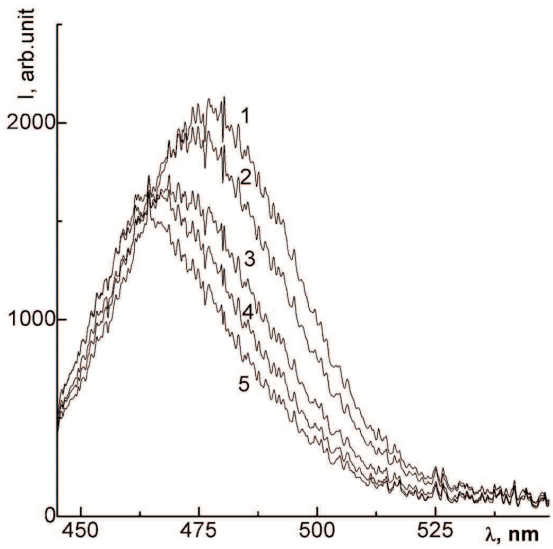


Fig. 3. EL spectra at the termination of the process of fast degradation of the InGaN/GaN heterostructure: *1–5* – in 60 s; *1* – $J = 44$ A/cm$^2$, $U_{\rm forw} = 5.2$ V; *2* – $J = 44 \div 31$ A/cm$^2$, $U_{\rm forw} = 6.3 \div 5.7$ V; *3* – $J = 31$ A/cm$^2$, $U_{\rm forw} = 6.3 \div 6.7$ V; *4* – $J = 25$ A/cm$^2$, $U_{\rm forw} = 6.9 \div 6.99$ V; *5* – $J = 19$ A/cm$^2$, $U_{\rm forw} = 7.7$ V

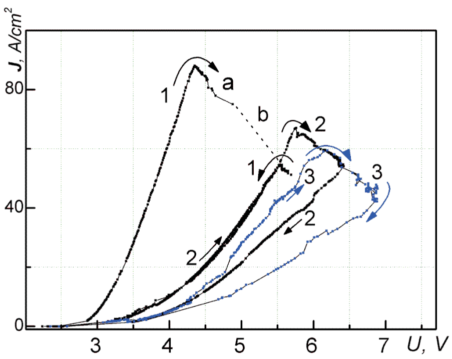


Fig. 4. Hysteresis of the CVC of the InGaN/GaN heterostructure on the cyclic change of the current. $T = 290$ K

structure. As seen from Fig. 2, the maximum of the *B*-band is shifted jumpwise (by $\Delta\lambda \approx 5$ nm) on the insignificant variation of $J$ from 44 to 56 A/cm$^2$. In this case, the change of $J$ from 0 to 44 A/cm$^2$ leads to the shift of the maximum of the *B*-band only by 2 nm. The increase in $J$ to 75 A/cm$^2$ causes the superfast degradation of locally inhomogeneously thermostressed structures, which is accompanied, like in [8–10], by AE damping with the course of time. In Fig. 3, we show the final stage of this process: the EL spectra recorded in 60 s under the invariable voltage of the source and the constant ballast resistance.

For the EL spectra recorded at $J = 44$ A/cm$^2$ prior to the AE occurrence (Fig. 2, curve *3*, the forward

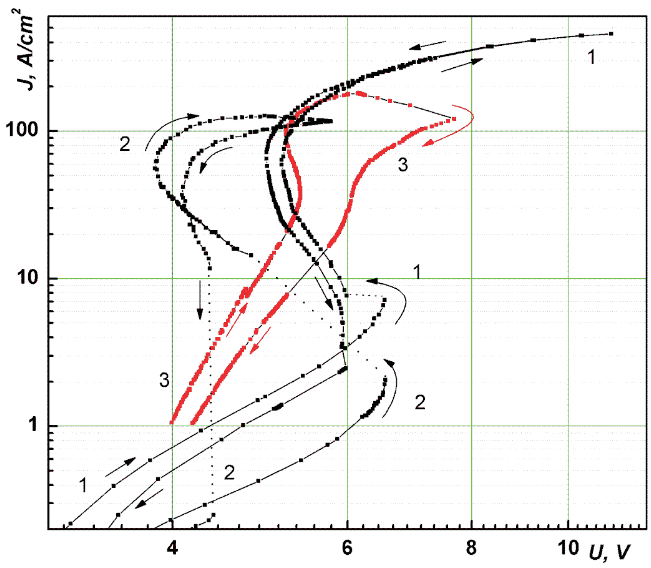


Fig. 5. Hysteresis of the CVC of heterostructures for the first cycle of a change of the current at $T = 77$ K: *1, 2* – $GaAs_{0.15}P_{0.85}/GaP$, *3* – InGaN/GaN; *1* – $t_{\rm ag} = 6\times10^8$ s, *2, 3* – $t_{\rm ag} = 6\times10^6$ s

voltage $U_{\rm forw} = 3.41$ V) and after the termination of AE (Fig. 3, curve *1* – $U_{\rm forw} = 5.2$ V), the values of $U_{\rm forw}$ and the maxima of the *B*-band of EL are significantly different (462 and 478 nm), which indicates the presence of considerable inhomogeneous LMS which are created and partially relaxed in the processes of AE and degradation.

In Fig. 4, we present the hysteresis of the CVC of the InGaN/GaN heterostructure on the cyclic variation of $J$ ($T$=280–290 K). In this case, all the three dependences have a section where $J$ decreases simultaneously with increase in $U_{\rm forw}$ under the AE occurence, which corresponds to the irreversible increase in $R_d$ on the relaxation of inhomogeneous TMS. The increase in $R_d$ depends on both individual peculiarities of the structure and $J$ and can occur slowly with $dU/dt \approx 0.005$ V/s and $dJ/dt \approx 0.16$ A/(cm$^2$·s) (curve *1*, section *a*) or rapidly with, respectively, 0.3 V/s and 10 A/(cm$^2$·s) (curve *1*, section *b*), and $J_{\rm cr}$ take the values given in Table 1.

Figure 5 demonstrates the hysteresis of the *S*-like CVCs of the studied InGaN/GaN and $GaAs_{0.15}P_{0.85}/GaP$ heterostructures for the first cycle of variations of $J$ at $T = 77$ K. The *S*-like CVCs at $T$<100 K are characteristic of $p-i-n$-structures and are caused by the presence of a deep level in the *i*-region [21]. In the InGaN/GaN structures under study, the role of an *i*-region is played by a quantum well [21]. But, in the $GaAs_{0.15}P_{0.85}/GaP$ and $Ga_{0.7}Al_{0.3}As/GaAs$ structures, quantum wells are absent, and the function of an $i$-region can be implemented by a metallurgical junction [6].

The studied $GaAs_{0.15}P_{0.85}/GaP$ structures (Fig. 5, curve *1*) with $t_{ag} \approx 6\times10^8$ s and $J_n = 6$ A/cm$^2$, in which the remarkable processes of natural ageing occurred [13], underwent no essential damages at $J$ up to 456 A/cm$^2$. In this case, the hysteresis of the CVC is small, which is indicated by the inverse course of the CVC. On the contrary, in the $GaAs_{0.15}P_{0.85}/GaP$ structures with lesser $t_{ag}$ (in Fig. 5, curve *2* corresponds to $t_{ag} \approx 6 \times 10^6$ s), $R_d$ increases irreversibly already at $J = 125$ A/cm$^2$, and the characteristic decreasing section of the CVC appears. In the InGaN/GaN structures (Fig. 5, curve *3*) after the degradation, the $S$-section on the inverse CVC is absent. The dash-dotted curve in Fig. 5 shows the fast (jump-like) change of $J$ and $U_{\rm forw}$. We did not perform the studies of AE because of the well-known problem of the ensuring of the reliability of results at $T \approx 77$ K. However, taking our results at higher temperatures (on the correlation of the growth of $R_d$ and the AE occurrence) into account, we may assume the existence of AE in this time interval.

In the InGaN/GaN structures identified by their CVC and farad-voltage characteristics as "broken-down" ones (with a small $R_d$ at small currents) without AE which was terminated, we registered the intense emission with $\lambda = 710 \div 1400$ nm in the region of the $p$-contact of, probably, a nonthermal origin at the threshold value of $J_t = 175 \div 310$ A/cm$^2$. The intensity and the spectrum of this emission do not depend on the direction of a current, but its intensity is proportional to $J$.

## 4. Discussion

The above-performed analysis of the ADS of AE indicates that the appearance of the maximum on a typical histogram (Fig. 1) corresponds to the wear-out of probably one-type (by their nature) sources with the approximately identical activation energy at a given constant value of the external influence [18, 19] which is $J_{\rm cr}$ in the case under consideration. At present time, the scientific literature contains no information about the ADS of AE in complex semiconducting structures on the action of external fields of different physical nature. Therefore, the exact identification of these sources of AE requires the further studies. Obvious (due to the registered discrete high-energy AE) is only the relation of these sources of AE to three-dimensional defects or complexes of one- and two-dimensional defects.

It is seen from Tables 1 and 2 that all critical $J_{\rm cr}$ (the AE occurrence and the increase in $R_d$) and maximal $J_{\rm max}$ (the destruction of a structure) current densities of structures with $t_{ag} = 6 \times 10^6$ is are significantly less than $J_{\rm cr}$ of structures with $t_{ag} = 6 \times 10^8$ s at all used temperatures. In addition, the values of $J_{\rm cr}$ and $J_{\rm max}$ for naturally aged structures at $T = 77$ K practically coincide, whereas $J_{\rm cr} < J_{\rm max}$ by a factor of 1.5–2 for structures with $t_{ag} = 6 \times 10^6$ s.

These results confirm our assumption [13] that the process of natural adeing decreases the number of defects of a heterostructure, which take an active participation in the processes of defect-forming and destruction (in the AE occurrence), and increases essentially the minimum energy of their activation (which can be reduced with increase in the temperature, as seen from Table 1). In this case, the typical ADS of AE (Fig. 1) indicate that the energy of individual signals of a discrete AE depends slightly on the external influence level and the activation threshold of a source.

In the process of natural ageing, the basic critical electrophysical parameters of a heterostructure are firstly improved, but then the irreversible degradation is started. It is worth noting the considerable similarity of our results and those obtained earlier in [9, 13, 16, 17] with the results in [22, 23] concerning the artificial ageing under the irradiation of the GaP structures by $\gamma$-quanta and fast neutrons.

It is obvious that TMS which arise in heterostructures are inhomogeneous, in particular, due to the difference in $\alpha_i$ of adjacent layers. The local inhomogeneity of mechanical stresses can be related to the inhomogeneity of the stoichiometric composition of epitaxial layers, which leads to local disturbances of the barrier height of a heterojunction [2] and induces the additional complicated redistribution of $J$ passing through a structure [2, 3, 7]. This can yield the appearance of temporary three-dimensional regions of TMS which are potential sources of AE.

The value of shifts in the EL spectra and their evolution with the creation of an infrared band, which was accompanied by AE at the relaxation of created TMS, indicate also the considerable local inhomogeneity of these TMS. For example, the shifts $\Delta\lambda = 16 \div 20$ nm of the $B$-band of EL in the InGaN/GaN structures and $\Delta\lambda = 20 \div 50$ nm of the red and green bands in the $GaAs_{0.15}P_{0.85}/GaP$ structures are accompanied by intense AE and exceed significantly the shifts $\Delta\lambda = 5 \div 7$ nm known from the literature [1, 12]. We note that, for the last shifts, AE was frequently absent in our experiments. The estimate of $T_{\rm over}$ in the frame of the well-known modifications of the Varshni relation [9, 12, 24] was carried out by us in [9] with the use of various data on shifts $\Delta\lambda = 20\div 50$ nm and gave too great values of $T_{\rm over}$ – up to 250–400 K.

It is clear that such values of $T_{\rm over}$ and $\Delta\lambda$ can be explained also by the following complicated collection of physical mechanisms, the assumptions about which were partially given in [9]: the movement of $p-n$-junctions in the gradient fields of LMS and TMS [26]; the overheating of the active region of a structure [11, 12]; a nonlinear behavior of the temperature-dependent coefficient of shift $\beta(T)$ and the different values of $\beta(T)$ for different bands of EL; changes of both the composition and electronic states of structural defects [5, 25]; the spreading of a $p-n$-junction at $T > 400$ K, *etc.* It is worth to mention the correspondence of the results obtained in [9] and [22] concerning the formation of new deep levels of defects in the infrared region (1.13–1.29 eV) on the essentially different (a forward current and a neutron irradiation) extreme influences on GaP heterostructures.

The irreversible increase of $R_d$ on both the sections with slow and fast variations of the CVC (Figs. 4 and 5) means, as usual, the formation and motion of dislocations, two- and three-dimensional defects in the crystal bulk and in the active region of a structure [5, 6]. Such newly formed defects act also as the additional scattering centers for carriers. As a result of the running nonequilibrium processes, there occur the activation and the wear-out of the sources of AE on a specific section of the CVC. Moreover, the more intense AE is registered on the "fast" section, where the CVC diminishes. This corresponds, obviously, to both the intense formation of defects and the change of the energy state of a significant number of defects.

The initiating factors of the appearance and motion of dislocations are the initial defects of the package and the existent LMS and TMS. But the irreversible change of a dislocation structure is also determined, in particular, by the ratio between the time interval of the steady action of internal stresses on the pairs of segments separated from the stoppers and the duration of their movement between the adjacent stoppers. Under conditions of the fast processes of formation and breaking of LMS with the release of mechanical energy in the form of a discrete (explosive, according to [15]) AE and the change of the magnitude (and the direction) of a force acting on these segments, one should not affirm the obligatory irreversibility of a change (deterioration) of the dislocation structure. At the same time, it is known that the irreversible degradation of parameters of a heterostructure on the passage of considerable $J$ is accompanied by the appearance of a network of dislocations in the active region of the $p-n$-junction [6]. This fact also explains both the long-term AE from the sources of AE, which are activated at $J_{\rm cr}$ and possess the significant volume and energy, and the destruction of the structure at $J_{\max}$ on the accumulation of a certain number of defects.

In the studied InGaN/GaN structures with $t_{\rm ag} = 3\times 10^6 \div 10^7$ s, where the number of the sources of AE with a small activation energy is else significant and decreases with increase in $t_{\rm ag}$ because of, probably, the enhancement of the threshold of their activation, the irreversible increase in $R_d$ (and, probably, the AE occurence) at $T = 77$ K (Fig. 5, curve *3*) begins at $J \geq 180$ A/cm$^2$. On the reversible CVC, the $S-$section is absent, which is related to the fast formation of a system of shallow acceptor levels in the quantum well of InGaN due to the appearance of dislocations in the active region and the violation of the condition that the concentration of thermally excited holes be much less than the concentration of deep centers of compensation in the quantum well [21].

The sequential wear-out of the sources of AE on the step-by-step increase in $J$ decreases both the available number of active sources (which emit the signals of AE at a given $J$ [14, 15]) of AE and the activity of the process of creation of new sources (in particular – due to a decrease in the probability of the interaction of acting sources of AE), which allows one to obtain $J \sim 50J_n$ in a stable way in aged structures at low $T$ without their instantaneous destruction. This is also indicated by the fact that the values of $J_{\rm cr}$ and $J_{\max}$ approach each other on a decrease in $T$ and an increase in $t_{\rm ag}$. In fact, this is the ideal situation, where two processes are running simultaneously: the destruction and AE which always precedes the destruction under other conditions. For this reason, AE is one of the leading methods of nondestructive control over a state of materials and structures.

The essential irreversible changes in the EL spectrum of heterostructures with the AE occurrence at $J_{\rm cr}$ indicate that the processes of defect-forming in a heterostructures are determined to a significant extent not only by point defects, but also by sources of AE (three- and two-dimensional defects which are similar by main parameters), whose number depends, in particular, on $t_{\rm ag}$ of a heterostructure and its $T$. The sizes of these defects in low- and nanodimensional structures can be comparable with both the thickness of epitaxial layers and, especially, with the thickness of the near-surface regions on the boundary of layers.

## 5. Conclusions

It follows from the complex studies of AE, CVCs, and the EL spectra that point and extended defects of different physical nature take a synchronous participation in the processes of defect-forming which are accompanied by AE on the passage of a current in light-diode low- and nanodimensional heterostructures on the basis of the InGaN and GaAsP compounds. These defects play the individual role in a change of electrophysical characteristics, in particular, in the reversible and irreversible evolution of EL spectra through a change of the profile of energy bands and levels on the relaxation of LMS and TMS.

This process of local reconstruction of the system of defects has the character of thermoactivation: with increase in the temperature, the threshold of the AE occurrence decreases, and, simultaneously, the number of active sources of AE increases. As the temperature decreases, the threshold current densities of the AE occurrence approach the limiting value when a heterostructure is destroyed. The processes of natural ageing in heterostructures change significantly the dynamics of AE and its typical parameters. In particular, these processes increase both the threshold current densities of the AE occurrence and the current densities corresponding to the destruction of heterostructures.


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АКУСТИЧНА ЕМІСІЯ ПРИ РЕЛАКСАЦІЇ ЛОКАЛЬНИХ ТЕРМОМЕХАНІЧНИХ НАПРУЖЕНЬ В ПРОЦЕСІ ДЕГРАДАЦІЇ СВІТЛОВИПРОМІНЮЮЧИХ ГЕТЕРОСТРУКТУР НА ОСНОВІ InGaN ТА GaAsP

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Р е з ю м е

Наведено результати досліджень кореляції акустичної емісії (АЕ) та оборотних і необоротних змін електрофізичних характеристик світловипромінюючих гетероструктур на основі InGaN та GaAsP в процесі їхньої деградації при протіканні прямого струму критичної густини. Встановлено, що процес локальної перебудови дефектної структури при протіканні струму, що супроводжується АЕ, має термоактиваційний характер – з ростом температури поріг виникнення АЕ знижується та одночасно зростає кількість активних джерел АЕ. Зі зниженням температури поріг виникнення АЕ наближається до межі руйнування, при цьому процеси природного старіння значно підвищують пороги виникнення АЕ і руйнування структури.