ELECTROLUMINESCENCE (EL) IN GaS:Ln^{3+} (Ln-Nd, Er, Tm)

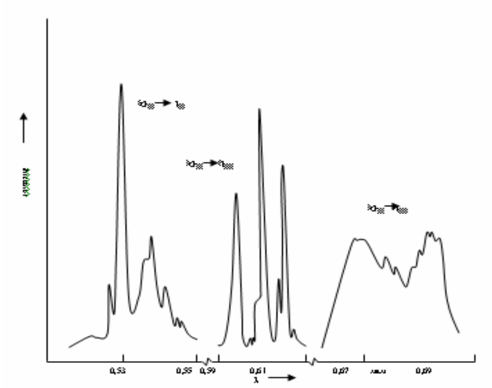
F.Sh. AYDAYEV, O.B. TAGIYEV
Institute of Physics of Azerbabaycan of Sciencies
Az-1143, Baku, H. Javid ave., 33

Excitation of EL was accomplished by the applied to a crystal, constants and variable electrical fields. Thus, the luminescence of the matrix and radiation caused by transitions of rare earth ions is observed.

Research of EL of rare earth ions in wide (-band-) gap semiconductors represents the big interest in connection with perspectives of reception of stimulated radiations with electrical rating and creations of plane solid-state display, oscillographic and television screens [1,2].

Investigation results of EL characteristics of monocrystals GaS:Ln^{3+} are presented in the given article. The samples with thickness from 70 up to 150mkm with sandwich contacts, made of In, Al, Ag etc, were used for investigation of EL.

Spectra of an electroluminescence in monocrystal GaS:Nd at 77K and 200Hz are shown on fig. 1. Narrow-band lines of radiation in an interval of wavelength on electroluminescence spectrum 0.53÷0.55 and 0.59÷0.61 mcm are caused accordingly by transitions of $^4G_{7/2}\rightarrow{}^4I_{9/2}$ and $^4G_{7/2}\rightarrow{}^4I_{11/2}$ of Nd^{3+}. It is known, that Nd ions have rich radiating ability in infrared area of a spectrum. In our researches intensity of radiation in infrared region is very weak. Therefore this part of a spectrum is not shown on fig. 1.



. *Fig.1*. EL spectra of GaS:Nd (T=77K, f=200H.

EL spectra of monocrystal GaS:Er are shown on fig.2. From all investigated transitions the most intensive was a transition $^4S_{3/2}\rightarrow{}^4I_{15/2}$.

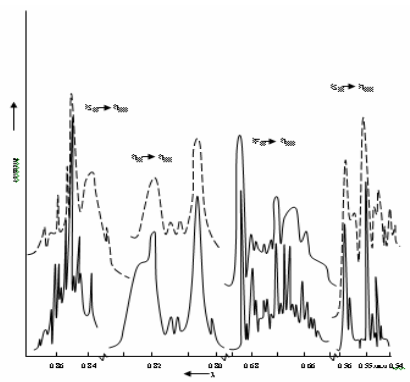


Fig. 2. Spectra of photo (continuous curves) and electro-luminescence (dotted curves) of monocrystals

Electroluminescence spectra of monocrystal GaS:Tm are shown on fig. 3. The area 0.79÷0.83 mcm is caused by transition $^3F_4\rightarrow{}^3H_6$, and 0.68÷0.72 mcm is caused by transitions $^3F_3\rightarrow{}^3H_6$ of Tm^{3+} ion.

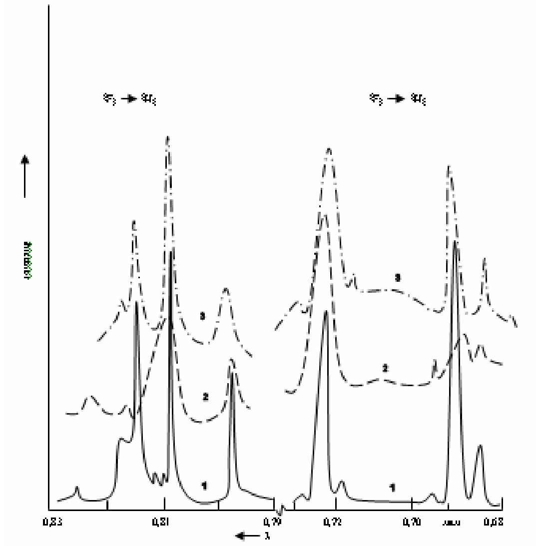


Fig. 3. Spectra of photo (curve 1 at 77K, curve 2 at 300K) and electroluminescence (curve 3 at 77K) of monocrystals GaS:Tm

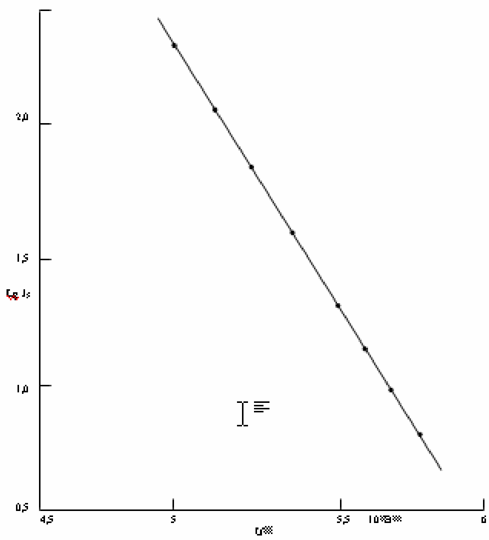


Fig. 4. Dependence of EL intensity on applied to the sample (GaS:Nd).

One of the most essential characteristics of electroluminescence, allowing to determine its mechanism, is the dependence of intensity of radiation on the applied voltage. This dependence for monocrystal GaS:Nd^{3+} is shown on fig. 4. Obviously, dependence of intensity of an electroluminescence on voltage submits to the exponential law [3]

$$I = I_0 \exp\left(\frac{b}{\sqrt{u}}\right) \quad . \qquad (1)$$

I_0 is defined by an external source of electrons, and parameter of exponent is defined by the value of area. Similar dependence for crystal GaS:Er is shown on fig. 5. Such character of dependence of EL intensity is observed also at excitation of samples by a constant electrical field.

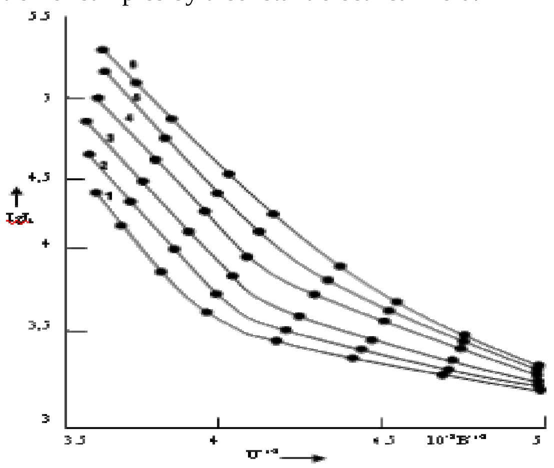


Fig. 5. Field dependences of EL intensity at different frequencies of applied variable field, at 77K ($^4S_{3/2} \rightarrow {}^4I_{15/2}$ GaS:Er); 1- 200, 2-300, 3-400, 4-600, 5-800, 6-1000Hz.

Exponential growth of EL intensity from voltage specifies that EL in the area of strong fields is caused by shock ionization of impurity centers. We also establish, that the relation of intensity of luminescence I_l to dark current I_c passing through a sample, also changes on the exponential law [4].

$$I_л / I_T = A \exp\left(-\frac{c}{u}\right) \quad . \qquad (2)$$

Such dependence for crystal GaS:Er is shown on fig. 6. Realization of such regularity also specifies the shock mechanism of excitation of an electroluminescence in GaS:Ln^{3+}. In the area of electrical fields where the deviation from exponential dependences is found out, the cubic site and a site of sharp growth of a current comes to light on current-voltage characteristics of monocrystals GaS:Ln^{3+}.

It is shown in work [5,6], that passage of a current in structures is In- GaS:Ln^{3+}-In is caused by double injection. Besides the visible luminescence in monocrystals GaS:Ln^{3+}, at small voltage is observed near to the cathode and with growth of voltage is distributed to the anode. Hence, it is possible to assume, that at small fields the injection electroluminescence phenomenon is observed.

It is known, that the mechanism of shock ionization is possible at presence of a strong field (≥10^5V/cm). However, in the investigated crystals, EL is observed in an interval of electrical fields $10^3 \div 10^5$ V/cm . Obviously, acceleration of carriers occurs on barrier of Shotki. It is possible, that the electroluminescence at fields of ≥10^5V/sm may be connected with microasperity of crystal, formed at doping of rare earth elements.

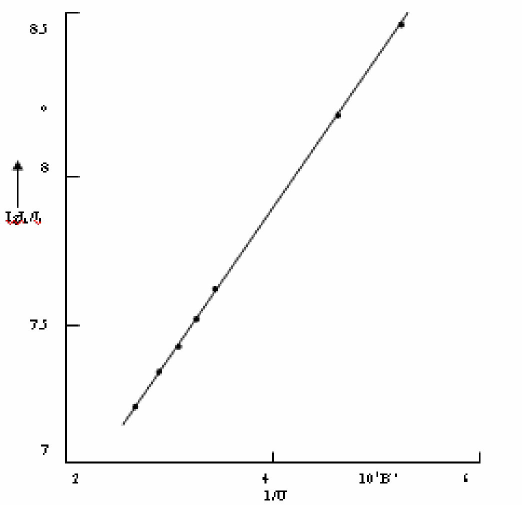


Fig. 6. Dependence of *Lg* $J_л$:J_m on U^{-1} for monocrystal GaS:Er at excitation by constant field *T*= 77 K, $^4S_{3/2} \rightarrow {}^4I_{15/2}$ Er^{3+}

The low-frequency peak is found on frequency dependences of EL intensity at 200 Hz (fig7). Intensity grows with increase of frequency from 20 up to 200Hz. With the further increase up to 10Hz intensity slowly decreases. Expression for a quantum output of radiation is received in work [7]:

$$P = \frac{\alpha N_a}{\alpha N_a + \beta N_t} \exp\left[-c_1 \frac{\beta N_t}{\alpha N_a + \beta N_t} \Delta t \exp(-\frac{E}{kt})\right] \qquad (3)$$

where N_a and N_b-concentration of activating and braising impurity, the C_1-constant, α and *β*- probabilities of capture of holes from a valent zone on levels of activating and braising impurity, *T*-time of holes redistribution , *E*-depth of activator deposition, *Δt* -is the certain part of the period *(δ)*: *Δt=δ/f* . Apparently from the formula (3), the quantum output grows with increase of frequency of the applied variable field. The increase of brightness of a luminescence observed on experiment at low frequencies, apparently, is caused by increase of a quantum output. With the further increase of frequency the quantum output does not play an essential role anymore as the power absorbed at the big frequencies, poorly depends on the frequency. The high-frequency area of this curve is well straightened in double logarithmic scale (fig. 7). It specifies on capacitor character of recession [8].

Temperature dependence of EL intensity of broadband radiation (λ_m=0,58mkm) contains three sites. EL intensity practically does not vary in the area of temperatures 77÷95K, that specifies the impurity character of energy absorption [9]. The inclination, which is equal to 0.70 eV is found above temperature 95K. As is known, the wide strip with a maximum at wavelength (λ_m=0,58 mcm is caused by transition of electrons from a zone of conductivity on p-type levels [10]. *P*-type levels grasp electrons from a valence zone with increase of temperature. Temperature dependence of EL intensity of transition $^4S_{3/2} \rightarrow {}^4I_{11/2}$ of Er^{3+} electrons repeats a course of temperature dependence of broadband radiation. Apparently, transfer of energy to ions Er3 + is accomplished through strips with maximum λ=0.58mkm. Similar results were received for monocrystal GaS:Tm [11].

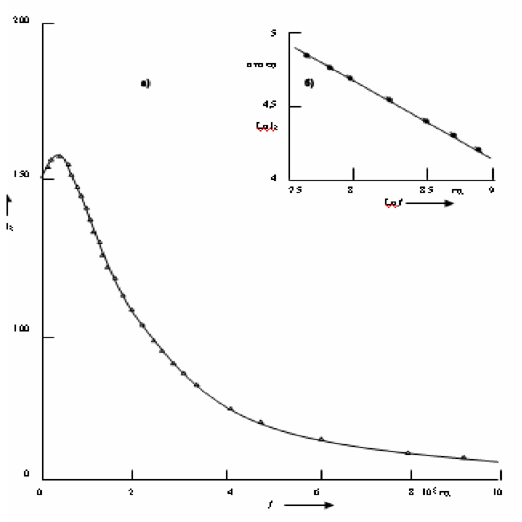


Fig. 7. Frequency dependence of EL intensity at 77K ($^4S_{3/2} \rightarrow {}^4I_{15/2}$ GaS:Er)

Electroluminescence in monocrystals GaS:Ln^{3+} is found at fields where the cubic law is broken to CVC (current-voltage characteristic) and enough amount of free carriers of both types is injected in volume of the semiconductor. The similar situation is formed at excitation of a crystal $h\nu > E_g$. The only difference is in the infusing of the electrical field ($E \geq 10^4$V/sm) applied to a crystal on capturing of carriers and in facilitating of the process of liberation of the located carriers (thermal field effect). Formed in volume of a crystal free carriers may recombine on interzoned transitions and through local conditions in the forbidden zone.

Thus, on the basis of experimental results it is possible to conclude, that found EL in monocrystals GaS:Ln^{3+} at relatively weak fields, EL mechanism is injection, and at more strong fields - shock ionization. GaS:Er at T=77K

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F. SH . AYDAYEV, O.B.TAĞIYEV

GAS:LN^{3+} (LN – ND, ER, TM) KRISTALLARIN ELEKTROLÜMINISENSIYASI

GaLn3(Ln – Nd , Er , Tm) kristallarında elektrolüminessensiya hadisəsi sabit və dəyişən elektrik sahələrində tədqiq olunmuşdur. Bu zaman nadir torpaq elementinə xas olan şualanma və həmçinin zonalar arası keçidə uyğun şüalanma müşahidə olunmuşdur.

Ф.Ш. АЙДАЕВ, О.Б. ТАГИЕВ.

ЭЛЕКТРОЛЮМИНЕСЦЕНИЯ (ЭЛ) В GAS:LN^{3+} (LN – ND, ER, TM)

Возбуждение ЭЛ осуществлялось приложением к кристаллу постоянных и переменных электрических полей. При этом наблюдается свечение самой матрицы и излучение, обусловленное внутрицентровыми переходами редкоземельных ионов.

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