

Polarized electroluminescence in gallium nitride

M. D. Shagalov and A. G. Drizhuk

Vologda Polytechnical Institute

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The effective polarized electroluminescence of zinc-doped gallium nitride is observed in the visible range of the spectrum. The special features of polarized radiation properties serve as a basis for proposing the existence of heretofore unknown mechanisms for radiative processes.

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Polarized electroluminescence (EL) is observed for the first time in the visible wavelength range. An IR source of polarized radiation based on gallium arsenide has been reported.^(1,2) In the case of diagonal tunneling of non-majority charge carriers in the *p-n* junction region the degree of polarization of radiation may theoretically attain ~60%.

In the case of broadband semiconductors of the A_3B_5 and A_2B_6 groups,^(3,4) polarized photoluminescence (PL) is associated as a rule with the presence of dipole-type radiative centers. However, polarized EL, which has a greater practical value, has not been observed in these compounds due to peculiarities of the mechanisms of radiative processes and the difficulties of obtaining light-emitting structures with fixed electrical properties.

Light sources that emit in the entire optical range of wavelengths have been produced on the basis of *n-i* GaN structures in which the insulating layer GaN is doped with zinc during growth. The possibility of obtaining radiation of a different color from GaN:Zn is explained by the peculiarities of implantation of zinc into the GaN lattice under the changing conditions of growth, and its tendency toward complexing.^(5,6) Although a large number of investigations exist, which are dedicated to the study of EL and PL in GaN, the mechanisms of the radiative processes in which the impurity states take part, are not fully understood so far.

In this work we report on a number of investigations of the electrophysical properties of GaN structures whose EL attains an intensity maximum at ~2.55 eV. The distinguishing property of EL is an ~60% polarization in the blue radiation. As is the case with a majority of broadband semiconductors, radiative processes with the participation of a dipole-type center are distinguished by a high effectiveness. The extrinsic quantum efficiency of a GaN light diode with polarized output exceeds by 1–2 orders the effectiveness of any other GaN light diodes and is 0.2–0.3%. There exists, however, a number of special luminescence properties of GaN which indicate heretofore unknown mechanisms for radiative processes with dipole participation, and which yield certain information about the structure of the zinc complex.

Figure 1 shows the PL and EL spectra for the same level of GaN:Zn excitation. The halfwidth of the emission bands for two excitation methods differs by a factor

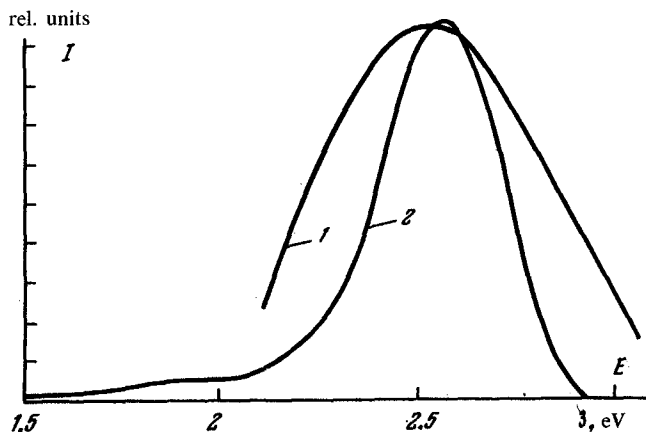


FIG. 1. Spectra of photo-(1) and electroluminescence (2) of zinc-doped gallium nitride.

greater than 2. Moreover, the blue radiation for the PL remains practically unpolarized (3–4% of polarized radiation is probably due to crystal inhomogeneity). The emission microstructure represents a cluster of radiating sections each 1–3 μm long over a distance of 5–10 μm . Measurements of the degree of polarization of radiation (P) of individual regions $\sim 5 \mu\text{m}$ in diameter show that P may attain maximum value of $\sim 80\%$.

The EL effectiveness of blue light diodes for any level of excitation may be increased in two ways. Heating from room temperature to 330–370 K leads to a twofold increase in the emission effectiveness, and cooling down to 77 K results, in addition to a 5–8-fold reduction in the radiation intensity, in an ~ 1.8 -fold broadening of the

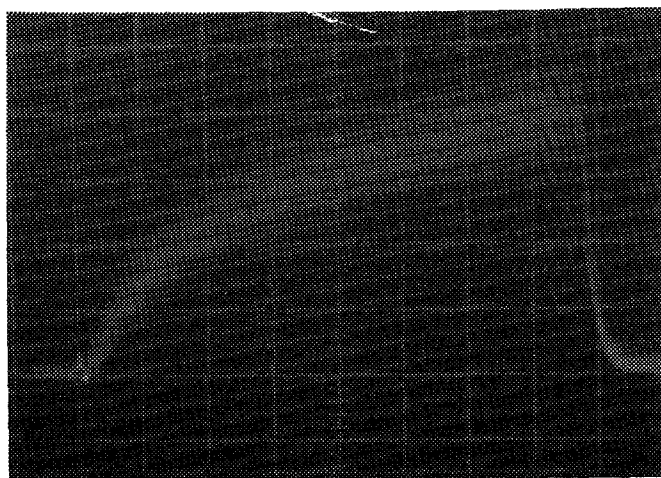


FIG. 2. Kinetics of buildup and decay of EL intensity for pulsed excitation (1 $\mu\text{sec/div}$).

spectrum. The PL of structures in this temperature range, as well as for a majority of A_3B_5 compounds, is characterized by temperature quenching of radiation intensity.

The EL intensity varies when the GaN crystal is placed in a magnetic field. For a given crystal orientation an ~ 2 -fold increase in the radiation intensity is observed in the ~ 10 -kOe magnetic fields.

The onset of emission for the blue light diodes occurs at comparatively low intensities of the electric field $\sim 4 \times 10^4$ V/cm, and exclusively for an inverse bias (a positive potential on the i -layer of GaN). Emission for the forward bias occurs only in the prebreakdown region. For the remaining yellow, green and dark blue light diodes the most effective emission is produced under a forward bias on the structure and at an electric field intensity of $\sim 5 \times 10^5$ V/cm.

The latter feature of light diode emission was observed in the course of investigating the kinetics of the rise and fall of the emission intensity. The shape of the curve showing a variation in the emission intensity when a rectangular voltage pulse is applied to the light diode is substantially asymmetrical (Fig. 2). The time constant of intensity buildup (τ) is 5–10 μ sec which is 50–100 times greater than the values of τ during the decay of the intensity. A value this high may in no way be associated with the possibility of modulating the emission by a constant harmonic signal up to 50-MHz frequencies without a noticeable decrease in the emission intensity.

On the basis of the foregoing features of the luminescence properties of GaN:Zn it may be assumed that the polarized blue radiation is a product of zinc complexes of the dipole type. The probability of transitions inside a complex increases substantially when an electric field of a given direction and amplitude is applied to it. The dipole orientation process may take place in a magnetic field.

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