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Bright Pure Green Emission from N-free GaP LED's

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Usually, liquid-phase epitaxial growth of GaP LED's has been performed by slow-cooling method and nitrogen as the emission centers have been doped for enhancing the luminescence efficiency. As mentioned in our previous paper [1] [2], the temperature change in growth caused bad influence for the crystallographic quality of the epitaxial layer. Moreover the peak wavelength of emission from nitrogen-doped GaP LED is longer than ~ 5600 Å at room temperature. On the other hand, the peak wavelength is 5520 ~ 5560 Å in N-free GaP LED. So the emission color of N-doped GaP LED is yellowish green or yellow.

In our previous paper [3] [4], it has been clarified that the high efficiencies of GaP or GaAlAs LED's could be achieved by a temperature difference method (TDM) under controlled vapor pressure (CVP). Also as reported in our paper [2] [3], the density of dislocation and deep levels in GaP epitaxial layer became minimum in the epitaxial layer grown by applying the optimum phosphorus pressure, and pure green emission can be obtained from nitrogen-free GaP LED.

In this paper, we report the N-free GaP LED whose external efficiency is over 0.1 %, applying TDM-CVP. Figure 1 shows J-V characteristics of GaP p^+n diodes at 77° K. Negative resistance appears at high injection current, which suggests that the diodes contain p^+-i-n structure at low temperature, but the phenomenon does not appear at 300° K. It can be recognized like that at threshold current which cause negative resistance, the high density injected carriers occupy nearly all recombination centers and the increase of conductance takes place. Capacitance-Voltage characteristics at 290° K and 77° K are shown in Fig. 2, capacitance of higher efficient LED (Type A) especially decrease at 77° K, which also suggest this kind of diode contain i-layer. Electroluminescence spectra were measured at 77° K with increasing current for corresponding to the negative resistance, as shown in Figs. 3 and 4. Intensities of emission peak P_C (D-A pair emission) were saturated above the threshold current and intensities of P_B (D-A pair emission) and exciton emissions continuously and sometimes remarkably increased.

The minority carrier lifetime of the diodes measured by impedance method is 1.7 μsec at room temperature, which is much longer than those such as a few hundreds nsec reported previously.

As mentioned here, the very high efficient pure-green GaP LED's can be produced even without doping nitrogen by applying optimum phosphorus pressure during epitaxial growth. The optimum phosphorus pressure to fabricate the brightest pure-green GaP LED's was confirmed to be coincided with the same pressure as the density of dislocation and deep levels in epitaxial layer could be reduced, moreover the resistivity of GaP became maximum in the heat-treatment experiment of GaP crystals under the controlled phosphorus pressure [4].

The brightest external quantum efficiency of nitrogen-free GaP in this experiment is 0.12 % at 20 A/cm^2 prepared at the optimum phosphorus pressure. The peak wavelength of pure-green emitted is ~ 5560 Å at room temperature.

References

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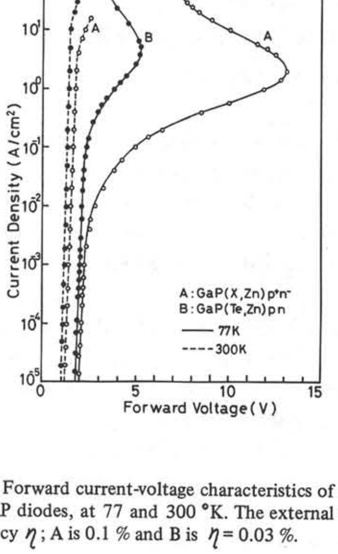

Fig. 1 Forward current-voltage characteristics of nitrogen-free GaP diodes, at 77 and 300 °K. The external quantum efficiency η; A is 0.1 % and B is η = 0.03 %.

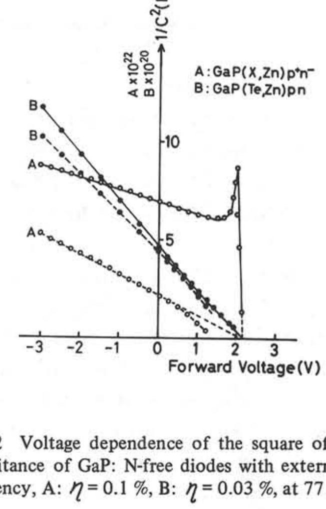

Fig. 2 Voltage dependence of the square of the inverse capacitance of GaP: N-free diodes with external quantum efficiency, A: η = 0.1 %, B: η = 0.03 %, at 77 and 300°K.

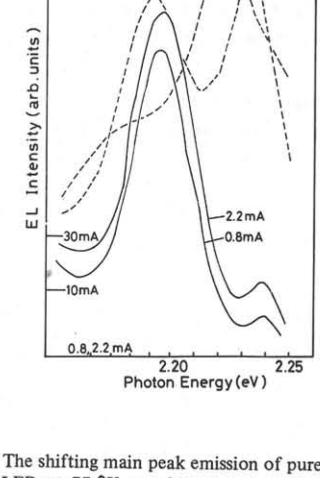

Fig. 3 The shifting main peak emission of pure-green GaP: N-free LED at 77 °K as a function of current. The green emission (hν = 2.22 eV) is dominant at the negative resistance region, the yellowish green emission (hν = 2.19 eV) is dominant at low current.

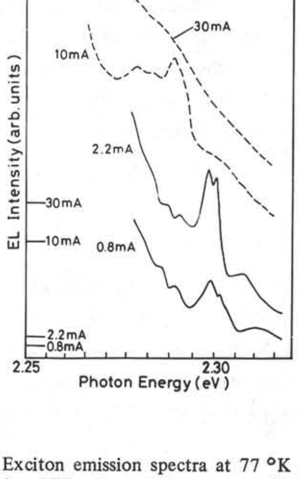

Fig. 4 Exciton emission spectra at 77 °K of pure-green GaP: N-free LED of external quantum efficiency η = 0.1 %, as a function of current.