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Concentration Profile of Zn-O Complex Centers in GaP Red-Emitting Diodes

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An accurate knowledge about the concentration of luminescent centers in light emitting devices, particularly about the concentration profile in the active region near the p-n junction, has been expected to be an essential guide to the great progress of the efficiency and reliability of the existing devices.

This paper reports the first direct determination of the concentration of Zn-O comlexes(the red-emitting centers) near the junction of GaP red-emitting diodes, by the use of a photocapacitance technique which has been developed for the detailed studies of oxygen deep donors in GaP[1-3] as well as an alternative technique of photo-induced currents.

Samples mostly investigated consist of double LPE layers with $n=7\times10^{17}cm^{-3}$ and $p=4\times10^{17}cm^{-3}$ grown on the LEC substrate with $n\sim10^{18}cm^{-3}$.

Prominent photo-induced changes in capacitance, reversible increase and decrease by the irradiation with a visible light above 2.0 eV and an infrared light between 0.3—0.8 eV, respectively, can be observed for a reverse-biased diode at about 100 K. Alternatively, a transient charge flow is also detected, which is induced by the irradiation with the infrared light. These signals are definitely attributed to the changes in the population of electrons on Zn-O states within a depletion layer, which is due to the optical transitions between the Zn-O level and the continuum bands. Measurements of the photo-induced capacitance or transient current under a variety of reverse voltages immediately give us direct information about the near-junction concentration profile of the Zn-O complex centers.

The sensitivity for detecting the concentration of Zn-O centers in typical diodes is $10^{14}cm^{-3}$, while that for oxygen donor concentrations is $10^{13}cm^{-3}$. It is because an effect of field ionization has to be taken into consideration for electrons on the shallower Zn-O states especially at high fields.

The concentrations of the Zn-O red-emitting center together with the Zn acceptor and O donor centers on the p side of the junction are profiled for a series of diodes with a variety of efficiencies. The average concentrations for three diodes with different efficiencies are exampled in the following table.

Sample	Efficiency (%)	Concentrations (cm^{-3}) Zn	O	Zn-O
A	4	4.2×10^{17}	1.8×10^{16}	6.0×10^{15}
B	1	4.0×10^{17}	0.8×10^{16}	1.0×10^{15}
C	0.1	3.8×10^{17}	0.6×10^{16}	0.2×10^{15}

It is pointed out that increasing the pairing probability for Zn and O near the junction by finding suitable annealing conditions has a key to the improvement of the efficiency and reliability of the devices.

References

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