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Contents of Non-Radiative Deep Levels and its Relation to Crystallographic Quality

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Epitaxial growth in the conventional method for LED fabrication has been based on the temperature lowering processing. In previous work we have reported that the defects introduced by the change in growth temperature affect the crystallographic quality[1)2)]. In this experiment, the epitaxial growth ~~were~~ was performed by a temperature difference method (TDM) under controlled vapor pressure (CVP). It has been clarified that the crystallographic quality of GaP changed dependent on the applied phosphorus pressure and a nearly perfect crystal was obtained by applying the specific vapor pressure (optimum vapor pressure).

This paper report the LED properties of GaP and the crystallographic quality of crystals as the function of vapor pressure. Figure 1 shows I-V characteristics of the GaP and GaAs p^+n diodes as a function of phosphorus and arsenic pressure. The slopes of I-V characteristics change dependent on the phosphorus and arsenic pressure, that of P_{GaP} = 67 Torr and P_{GaAs} = 9.8 Torr are most ideal. The leakage in the lower current region suggests the existence of deep levels or defects[3)]. The photocapacitance characteristics ~~was~~ were measured in order to obtain a deeper understanding of deep level impurities in the LED's. The photocapacitance spectrum typical of LED's at each phosphorus pressure was shown in Fig.2. The shape of the spectrum for each phosphorus pressure is almost the same, however, that of diode grown under the optimum pressure (75 Torr) for the crystallographic quality has no peaks in the lower energy side. Therefore, these results suggest that the introduc~~er~~tion of deep impurities or defects can be suppressed by applying the optimum pressure.

The relation between the carrier concentration and the brightness of LED's is shown in Fig.3. In the case of processing without CVP, the scatter is considerably large and is relatively small at P_{GaP} = 75 Torr. The data points at P_{GaP} = 75 Torr are concentrated in the brighter region. From above data, this optimum phosphorus pressure (P_{GaP} = 75 Torr) can produce brighter light emitting diodes and it means that non-radiative center (defects) is reduced by the application of this pressure. Also the lifetime of minority carriers measured by the impedance method shows the minimum at the same pressure.

This optimum pressure is coincided with that of the crystallographic quality[1)2)] and the heat treatment of crystals[4)5)].

Therefore, we confirmed that the radiation efficiency of LED, and content of deep levels changed in cooperat~~e~~ion with the crystallographic quality. Highest value of external quantum efficiency in nitrogen-free GaP is 0.03 % prepared at P_{GaP} = 75 Torr.

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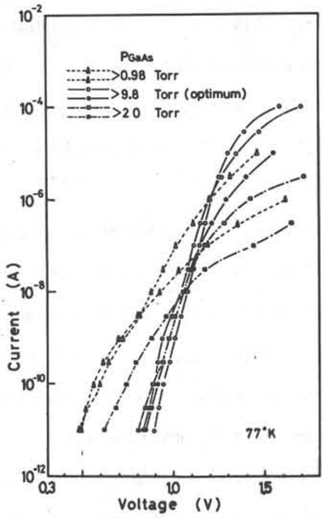

Fig. 1 (a)

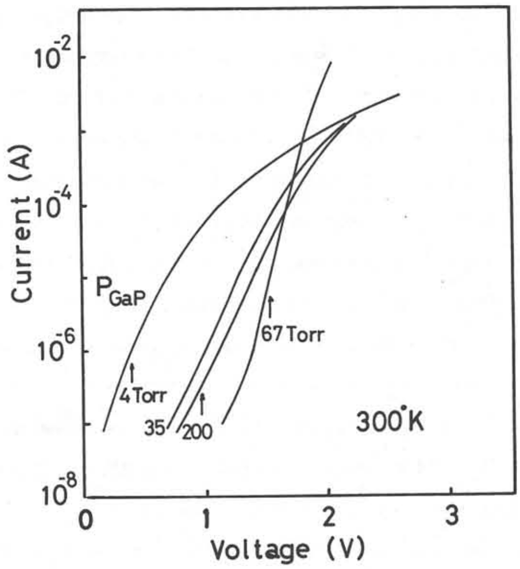

Fig. 1 (b)

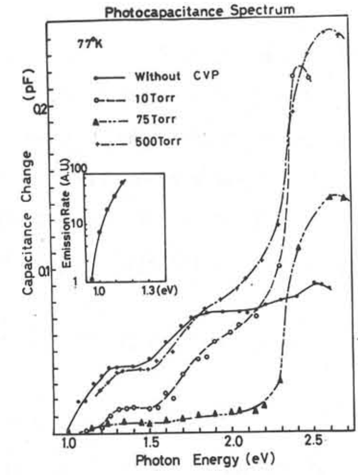

Fig. 2

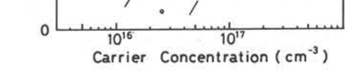

Fig. 3