B—2—6 GaP Green LED Degradation Associated with Nonstoichiometric Layer Created during Electrode Formation Process

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It is known that a large amount of gallium diffuses out of GaAs and GaP into an aurum alloy electrode during heat-treatment for ohmic contact formation[1]. It is presumed that the defects associated with Ga vacancies are created during the heat-treatment. Some point defects influence the degradation in light-emitting diodes and semiconductor lasers as a result of the so-called recombination enhanced defect motion[2]. In the present work, GaP:N green LED degradation was investigated in association with the electrode formation processes.

Two kinds of GaP green LEDs were fabricated. The LED fabrication processes were the same for these LEDs besides the p-type layer electrode formation processes. The processes for sample A were as follows. Au-Be alloy was evaporated on the diode wafer p-type layers. The photo-engraving process was performed on the aurum alloy. The remaining electrode area was 20% of the surface area. The wafers were heat-treated at 500°C for 20 minutes in order to get a good ohmic contact. For sample B, Au-Be alloy was also evaporated in the same way. Then, the wafers were heat-treated. The photo-engraving process was performed after the heat-treatment.

Because gallium diffuses into the aurum alloy electrode out of GaP during the heat-treatment, a degenerate layer will be created beneath the electrode. The degenerate layer for sample A will be confined to the area beneath the electrode, while it will cover all the surface for sample B.

In Fig. 1, electroluminescent efficiency ratios are plotted versus operating time for both samples A and B in three lots, respectively. Light output degradation for sample A was 9% of the initial value on the average for the 3 lots, whereas it was 45% for the case of sample B. This degradation for sample B can be attributed to the fact that the degenerate layer covers all the p-type layer surface, because there are no differences in the LED fabrication processes between samples A and B, besides the p-type layer electrode formation processes.

It was found that this degradation was caused by the decrease in the minority-carrier lifetime in the light-emitting region, rather than the increase in the nonradiative recombination current in the space charge region.

In order to investigate whether or not the defects, being responsible for

the LED degradation, were present in the p-type layer surface region, about a 3 μm p-type layer was removed by the wet etching process. In Fig. 2, electroluminescent efficiency ratios are plotted versus operating time for both samples A and B with and without surface removing. For sample B, surface removing improves the LED reliability, which suggests that the defects are present in the surface region.

The defects may be mobile during the heat-treatment. Therefore, the heat-treatment was performed for sample B. In Fig. 3, electroluminescent efficiency ratios are plotted against operating time for sample B with and without the heat-treatment. The heat-treatment also improves the LED reliability, which suggests that the defects are mobile and go out of bulk crystals during the heat-treatment.

The following equations were presented by Vechten[3] for creating the vacancy complex $V_{Ga}^{-}P_{Ga}^{2+}V_{Ga}^{-}$.

$$V_{Ga}^{-} + P_P \longrightarrow P_{Ga}^{2+} + V_P^{+} + 4e^{-}$$

$$P_{Ga}^{2+} + 2V_{Ga}^{-} \longrightarrow V_{Ga}^{-}P_{Ga}^{2+}V_{Ga}^{-}$$

It was also suggested[3] that the complex would be an efficient nonradiative recombination center, and exhibit recombination enhanced defect motion. In the present work, the same complex might be created during LED operating time, and be responsible for the LED degradation. From these results, it is expected that much attention will be paid to the electrode formation process in order to improve LED reliability.

1) J. M. Poate, K. N. Tu and J. M. Mayer, Thin Films-Interdiffusion and Reactions, P 410 (John Wiley & Sons, New York, 1978).

2) D. V. Lang and L. C. Kimering, Phys. Rev. Lett. 33, 489(1974).

3) J. A. Van Vechten, J. Electron. Mater. 4, 1159(1975).

Fig. 1

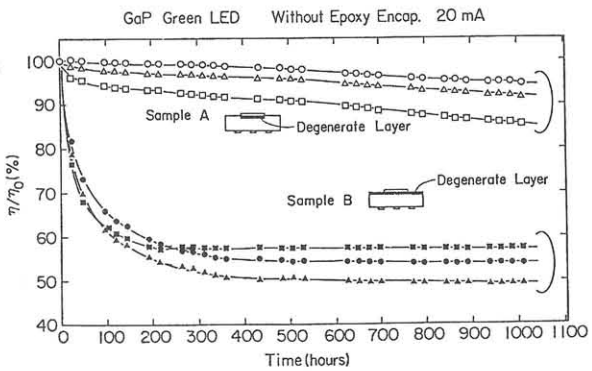

Fig. 2

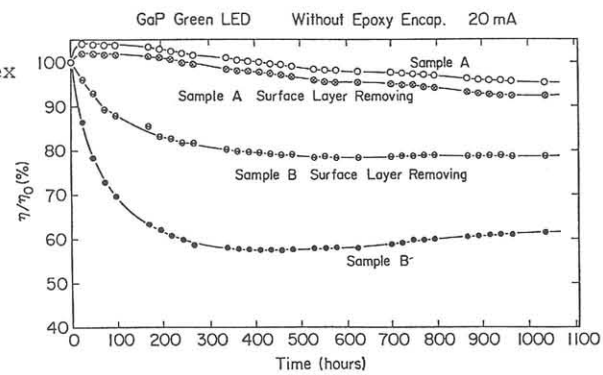

Fig. 3