DEGRADATION OF GaP:N LEDs

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The degradation of light output with operating time has been studied for nitrogen doped GaP light emitting diodes fabricated from vapor phase epitaxial material. The degradation is found to saturate at a non-zero value of efficiency. The process is characterized in terms of a degradation rate constant and the saturation value of efficiency. The rate is found to be a strong function of current density during operation and to a lesser degree materials parameters such as dislocation density. The saturation value appears to be independent of these parameters.

The degradation is specifically associated with a decrease in the minority carrier lifetime in the p-side of these diffused LEDs. A model for the generation of non-radiative recombination centers which describes the degradation process quantitatively is presented.

Key words: LED degradation, GaP, light emitting diodes.

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Introduction

One of the outstanding features of solid state devices is their reliability and long operating life under normal operating conditions. However, in certain devices, the operating life is short enough to limit their usefulness. A prime example is the solid state injection laser where operating times of over 10,000 hours have only recently been achieved. Similar, though less severe, problems are encountered in incoherent LEDs operated at high current densities. In fact, many similarities are observed between degradation characteristics in the two types of devices.

One well established mode of failure in injection lasers is due to the generation of dislocation structures which because of their appearance in electroluminescence images are denoted dark line defects (1,2) or DLDs. This is less commonly observed in LEDs although similar defects have been observed by Mettler et al. (3) and Baird et al. (4) in GaAs diodes and Petroff et al. (5) for GaP:N green emitting LEDs. In the latter case, the defects were too small to be seen in the EL image but the distinction seems to be only one of size. Recently, Iwamoto and Kasami (6) found that mechanical stress present during operation produces well defined DLDs in GaP:N LEDs.

The most commonly reported degradation mode in GaAs and GaAs$_{1-x}$P$_x$ LEDs is related to growth of the non-radiative space charge recombination current (3,4,7-9). Similarly, for Zn-O doped red emitting GaP diodes, the degradation has been reported to be due to an increase in the space charge recombination current (10) or a decrease of injection efficiency onto the p-side of the junction (11). Impurities, particularly Cu, have been implicated in this mode for both GaAs (8) and GaP (10) diodes. Passivation of the surface has been found to effectively reduce the degradation in certain device structures (10,11). In GaP:N diodes, the degradation has also been linked to an increase in the space charge recombination current (12). Another mode of degradation is a decrease in the radiative recombination efficiency due either to an increase in the non-radiative center density (13-17) or to a decrease in the radiative center concentration (18,19).