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Lifetime and reliability of sensor laser

Abstract:
Degradation analysis is a crucial issue for the improvement of sensor laser diodes. Degradation occurs in three different modes: rapid, gradual and catastrophic. It can be located inside the cavity or at the facet mirrors. Each type of degradation presents its own signature and different crystal defects appear associated with them. The main physical mechanisms responsible for laser degradation are analyzed showing the relation between the main degradation modes and the different materials properties of the laser structures.

Keywords: Lifetime, Laser Sensor, Reliability, Laser Diodes

Detailled explanation

Introduction

Sensor laser diodes cover a broad spectrum of applications in all types of electronic and electro-optical circuits, starting from its use in opening automatic doors, electric elevators, televisions, communications, laser printers, video, computers, to full-resolution cameras and high-capacity analysis (CCD).) Therefore, it was necessary to estimate and reliability of sensor laser. All applications need long lifetime devices, and therefore, reliability is a very crucial issue of sensor laser diode technology. A great effort is devoted to understanding the main causes of laser failure, in view to improving their lifetime and to extending the range of their applications.The degradation of the laser diodes occurs in different modes, which have their own signature depending on the architecture and composition of the laser. The most common lasers are based on lattice matched AlGaAs/GaAs, InGaAsP/InP and strained InGaAs/GaAs heterostructures. These lasers have been the object of an extensive literature, in spite of which a full understanding of the degradation is not yet available. A major problem to achieve such an understanding is the complexity of the laser structures and the diversity of factors that can induce degradation. Amongst others, one can consider the perfection of the substrates, layers and interfaces that constitute the material support of the laser, the architecture of the lasers that can induce defects and strain, the processing steps, like metallisation and facet coatings, and the packaging step. These factors, inherent tothe structure of the laser, interact among themselves and with external factors as temperature, current injection, optical power and ambient atmosphere, leading to complex degradation mechanisms.

Degradation Modes

A laser diode lifetime can be described with the well-known bathtub curve, which includes an early failure period, a random failure period, and a wear-out failure period. The failure rates in the early failure period are typically due to assembly and major semiconductor defects but these weak devices can be screened out with a well-designed burnin process. The wear-out failure period is characterized by an increasing failure rate at the end of a laser's life. In between early failure period and wear-out failure period is the random failure period, which represents diode's operation life with a relatively stable failure rate. Theoretically, the failure time is a function of current, power and junction temperature, as indicated in equation (1), where I is current, P is power, A is the acceleration parameter of current and power, Ea is the activation energy and k is Boltzmann constant $t(f) = Ae^{(Ea/KT)}$

The main degradation modes are: dislocations that affect the inner region, metal diffusion and alloy reaction that affect the electrode, solder instability (reaction and migration) that affect the bonding parts, separation of metals in the heat sink bond, and defects in buried heterostructure devices.

These modes are enhanced by current during ambient temperature operations.Facet damage due to oxidation is enhanced by light or moisture and is particular to laser diodes. Note that for photodetectors the degradation mechanisms are different but the same Arrhenius relationship can be used to determine lifetime of the device given different operating temperatures. The same relationship holds with the activation energy being ~ .7 eV for infrared detectors. Also it is important to note that the criteria for detector lifetime degradation is based on receiving an unacceptable signal to noise ratio output as a result of the accelerated temperature life test.

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