# Optoelectronic Devices Failure Mechanisms and Anomalies

## Light Sources

Light sources (optoelectronic semiconductors) have failure modes and concerns similar to other semiconductor devices. Table 1 summarizes common failure modes and mechanisms of LEDs and laser diode devices.

LEDs have two primary failure modes described in a and b. Assessment and selection of manufacturers who adequately and consistently control their processes is important in eliminating these controllable defects.

a. Cratering occurs when a crack develops under the ball bond metallization zone from stress to a bond wire that pulls the chip out, leaving a void or "crater'. This is usually a result of an incorrect ball bonding process such as excessive pressure. It can also be caused by tension on the bond wire caused by incorrect looping of the bond wire, or when the power density of input pulses exceeds the capabilities of the device, or by a contaminated bond pad. Cratering can also be a result of vibration or shock to the device during handling. To assess the process, a sample needs to be de-encapsulated (PEMs) or de-capsulated (DIPs/Cans) and inspected/tested for bond/chip integrity. Similarly, failed devices can be subjected to failure analysis.

b. Die attach migration is a failure mode which shunts the light producing region of the junction and reduces optical transmission. This is most typical of LEDs that have silver-filled epoxy die attach materials, but it can also occur in solder eutectic die attachments. The die attach material creeps up the side of the die and may eventually short it out. This phenomenon can be observed with normal visual inspection techniques. This failure mode is usually caused by using too much die attachment material during assembly, and excessively high temperatures and pulse energy levels will accelerate the failure process.

Laser Diodes may fail in two ways, gradual degradation or catastrophic failure. Gradual degradation may be caused by (1) Electrostatic Discharge (ESD) damage experienced by the device, or (2) defects in the materials used in the laser diode or the fabrication process from which it is made, and from moisture ingression that can occur from inadequate hermetic sealing, or the intrinsic moisture absorption characteristics of encapsulating materials. The time to failure of laser diodes can be determined on a statistical basis when the failure mechanism is known and a homogeneous product has been evaluated by statistical sampling of a controlled lot. Latent defects from ESD and moisture ingression are not predictable as the extent of internal ESD damage, and future environmental conditions for moisture ingression, are unknown variables.

Catastrophic failures from predictable wear-out and operating temperature related characteristics could be determined statistically.

Table 1. Common Failure Modes and Mechanisms of LEDs and Laser Diodes

| Failure Mode | Failure Mechanisms | Recommendation |
|---|---|---|
| Facet damage | Pulse width and optical power density | Apply anti-reflection coating to facets |
| Laser diode wear-out | Photo-oxidation, contact degradation and crystal growth defects | Coat facets, reduce temperature and current density and use high quality materials |
| Laser diode Instability | Reflection of laser output power | Apply anti-reflection coating; defocus the graded index-coupling element |
| Shorted outputs | Whisker formation | Anticipate system lifetime and temperature solder tolerances |
| Dark line defects | Non-radiating centers | Material selection and quality control |

## Optical Fibers, Cables and Connectors

Optical fibers, cables and connectors are considered passive device elements of a fiber optic network system that play an important role in the overall effectiveness of a fiber optic network. Table 2 summarizes some typical failure modes and mechanisms for optical fibers, cables and connectors. See the section on Connectors for some connector failure concerns, as applicable, to portions of the optical connector assembly.

Table 2. Common Failure Modes and Mechanisms for Optical Fiber and Cable

| Failure Mode | Failure Mechanism | Recommendation |
|---|---|---|
| Cable open circuit fracture | Stress corrosion or fatigue due to microcracks | Residual or threshold tension less than 33% of the rated proof-tested tensile strength |
| Cable intermittent | Hydrogen migrates into the core of the fiber | Design cables with materials that do not generate hydrogen |
| Cable open circuit breakage | Temperature cycling, ultraviolet exposure, water and fluid | Design a jacket that prevents shrinking, cracking, swelling, or splitting |

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|---|---|---|
| | immersion | |
| Cable opaque circuit inoperative | Radiation exposure | Design to be nuclear radiation hardened |

**Detectors**

Detectors exhibit failure modes and mechanisms in common with their semiconductor counterparts. Table 3 summarizes some common failure modes and mechanisms for semiconductor detectors.

Table 3. Common Failure Modes and Mechanisms for Semiconductors Used in Fiber Optic Detectors

| Failure Mode | Failure Mechanism | Recommendation |
|---|---|---|
| Dark current (PIN diodes) | Fracture of lead | InGaAs or In layer grown on active region and reduce the temperature |
| Dark current (avalanche photodiode) | Thermal deterioration of the metal contact | Select an APD at 1.3 $\mu$m and reduce the temperature |
| Open circuit (all) | Fracture of lead-bond plated contacts | Use evaporated contacts |
| Short or open circuit | Electrochemical oxidation, humidity | Use hermetically sealed packages |

**Optocouplers**

Optocoupler devices may experience a significant reduction in the current gain with gradual degradation of light output from the emitter. Current gain of an optocoupler is specified as the ratio of output current to input current, expressed as a percentage for a specified input current. This is called the current transfer ratio (CTR), and a reduction in gain of the optocoupler expressed as a change in CTR over time is known as *CTR degradation*. Excessive CTR degradation, or gradual degradation in marginally designed systems, may result in significantly reduced performance and eventual system failure. Considerations of CTR degradation needs to be addressed in optical system designs.