Agilent Technologies
Innovating the HP Way

Safe Handling Fundamentals for Premium InGaN LEDs

ESD (Electrostatic Discharge)

Application Note 1142

Introduction

The circumstances that cause stress failure are important for manufacturers and end users to understand. Electrical damage may occur on many electronic components by electrical over-stress (EOS) or electrostatic discharge (ESD). In some components, the two types of failures can look similar or identical. This document discusses ESD safety practices with a focus on Indium Gallium Nitride (InGaN) light emitting diodes (LEDs). InGaN LEDs are the new generation of blue and green devices. They are extremely sensitive to ESD damage. Damaged devices can appear dim, dead, short, or with low V_f or V_r. Agilent Technologies' InGaN LEDs are **"Class 1"** classified. They can survive 20 V bias with the machine testing and 130 V by the human body model. Other examples of "Class 1" devices include unprotected MOS, junction field effect devices, and low power thin film resistors.

For a more detailed explanation and general application of ESD sensitive devices, please review Agilent Technologies document, A-5951-1589-1, *Workmanship Specification for ESD control*. It can be obtained through your local Agilent Technologies representative or by calling 1-800-227-8164 (USA).

1.1 Terms and Definitions

Antistatic: This term refers to the prevention of triboelectric charge generation. It is not a material type. Materials can be treated with an antistatic agent to reduce the generation of static charges. This property is not dependent upon material resistivity.

Charged Device Model (CDM): A mathematical representation which imitates the consequences of a part becoming charged by handling or improper packaging and is then being discharged. Since contact resistances are typically low in these cases, large, short duration currents can result, e.g. 10 amps for 1 ns (nanosecond).

Class 1, 2, 3: Classifications of ESD damage threshold specified by MIL-STD-1686A.

- Class 1: susceptible to damage from human body model (HBM) ESDs of 1999 volts or less
- Class 2: susceptible to damage from HBM ESDs from 2000 to 3999 volts
- Class 3: susceptible to damage from HBM ESDs from 4000 to 15,999 volts. Agilent has elected to identify all devices sensitive to HBM ESDs less than 16,000 volts as ESD sensitive.

Conductive: A physical property of material to allow charge movement. Charges move more freely in highly conductive materials. A static shielding enclosure (Faraday cage) requires use of conductive material. Defining standards are outlined in the *Workmanship Specification for ESD Control*.

Dissipative: A physical property of a material which allows charge movement. Dissipative materials conduct charges less freely than conductive materials. Defining standards are outlined in the *Workmanship Specification for ESD Control*.

Electroluminescence: The emitted light from a LED caused by applying sufficient forward bias current.

ESD: Electrostatic Discharge. A sudden redistribution of static charge which can be damaging to sensitive components.

ESD Certified: A person who has successfully completed ESD training and demonstrates proficiency in procedures for safe handling of ESD sensitive items in a particular job or location.

ESD Coordinator: An individual responsible for ESD control implementation in all or part of an entity.

ESD Sensitive: A part, assembly or product which can be degraded or damaged by ESD. There are ESD sensitive parts in nearly every family of electronic components containing thin films or insulators, including resistors, capacitors and semiconductor devices. Agilent has defined ESD sensitive items as those that are degraded or damaged by HBM ESDs of less than 16,000 volts. InGaN LEDs are more sensitive (some with HBM ESD thresholds less than 200 volts).

Faraday Cage: A closed conductive container which provides ESD protection because all external electrical fields terminate on its outer surface. A static shield formed into a closed container. No externally caused field is detectable inside a Faraday Cage. This is the best form of protection of ESD sensitive items which may be transported or stored in static unsafe areas.

Human Body Model (HBM): A mathematical representation which imitates the consequences of a charged person touching a part. The representation is usually an equivalent circuit with a charged 100 pF capacitor in series with a 1500 ohm resistor.

Ionizer: A source of charged air molecules (ions) which are attracted to and neutralize static charges of the opposite polarity. Ionizers for static charge control produce large, approximately equal numbers of air ions of both polarities. Ionizers for airborne particle precipitation are not necessarily suitable for ESD control, since they may generate only one ion polarity, and may also radiate a strong electric field.

Latent: Hidden damage caused by ESD, which remains undetected during test but results in eventual failure.

Machine Model (MM): A mathematical ESD discharge model representation imitating the consequences of a charged machine touching a part. The circuit is modeled with a 200 pF capacitor and a 0 ohm resister. Although an inductance value is not specified, most ESD equipment manufacturers place a 450 nH inductor in the discharge path.

Portable Workstation: A static-safe work surface, with a means for connecting it to ground, which can be easily carried or moved (such as a cart) from one location to another.

Shoe Strap: A temporary appliance installed over non-ESD safe street shoes for the purpose of connecting the human body to grounded conductive flooring. Specific types may be constructed for use in grounding the heel or toe, and might be called “heel grounders”, “toe grounders”, or “foot grounders”. Some varieties are intended only for temporary use.

Static Charge: A positive or negative electrical charge at rest on the surface of a material, which generates an electric field and can be the source of damaging ESD.

Static-safe: Complying with all appropriate ESD control measures.

Static Shield: A conductive surface which completely encloses one or more items.

Static Voltmeter: An electronic instrument capable of measuring static voltage by detecting the electric field. These instruments must be used at a specific distance (usually 1 to 2 inches) from the charged object to give accurate voltage readings. A static voltmeter has a “field of view” with an included angle of from 90 to 180 degrees, so it is only accurate when measuring the voltage on objects much larger than their field of view.

Triboelectricity: The transfer of charge by contact and separation of two surfaces. This charging by “rubbing” is a common source of static charge generation.

Topical Treatments: Applied to or effective on the surface, as in topical antistatic treatment. Such treatments reduce the tendency of a material to tribocharge by coating it with an antistatic chemical film. These films are temporary and sensitive to environmental influences, such as wear, heat, and moisture. The chemicals involved may also contaminate other surfaces.

V_f: Forward bias voltage.

V_r: Reverse bias voltage.

Wrist Strap Device: An ESD control assembly for grounding the human body. A wrist strap device consists of a wristband and a detachable cord.

1.2 Background

Static charge build-up is very common. Positive charge can be carried by materials such as air, human skin, hair, and glass while negative charge can be carried by other materials like silicone, rubber, Teflon, and most plastics. There are also “relatively neutral materials” such as wood-based products or conductive metals. Typical static voltages can range from a few volts to thousands of volts. Relative humidity also plays a major role in ESD control. In general, higher humidity results in lower static charge build up.

2. Effect and Appearance of ESD Damage on InGaN Device

ESD damage usually happens in discrete events. For the InGaN LEDs, discrete events are described as a voltage or current pulse discharged in the forward or reverse bias condition. Reverse and forward current leakage is characteristic of damaged devices. In addition, devices can appear shorted, dim, dead (no light), or exhibit low V_f or V_r . Low voltage ESD damaged devices, typically seen as small dark spots in the light emitting area, can be observed at low currents during electroluminescence. At higher voltages (around 2 kV for the HBM), burned metal around the cathode bond pad is common. This type of ESD damage is distinguished from EOS damaged devices where the anode pad is charred.

3. ESD Models

When a charged person comes in contact with an uncharged device, a rapid discharge takes place. The Human Body Model (HBM) simulates this type of ESD event by modeling the human capacitance and resistance value. This model is well characterized and widely accepted in the U.S. (MIL-STD-883D). Figure 1 shows a human-body ESD circuit model. The RC components are 1,500 ohms and 100 pF. These values represent a standing individual discharging directly from the skin. The HBM ESD test system has a variable high voltage power supply which ranges from 0 to 15,000 volts DC.

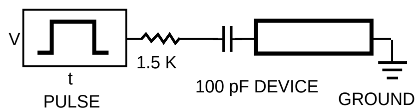

Figure 1.

The machine model (MM) originated, and is commonly used, in Japan. According to EIAJ ED-4701 Method C-111, the model consists of a 200 pF capacitor, discharged through the device at 0 ohm. The model does not specify an inductance value. However, ESD test equipment manufacturers typically place a 450 nH inductor in the discharge path, limiting the maximum rate of current increase. The peak current generated by the MM is larger than HBM, due to a lack of a resistor. Thus, devices are ESD damaged at lower voltages in the MM than the HBM.

4. ESD Classifications

The Agilent InGaN material is classified as “Class 1”. Any manufacturing line or workstations where InGaN devices are handled should be rated at 50 V or below.

5. ESD Requirements

All individuals handling InGaN LEDs entering or using ESD safe areas should be trained to understand ESD and be able to prevent it. Specifically, any person handling InGaN LEDs should wear ESD certified smocks with buttoned front, conductive wrist straps, and ground should be checked every time the person re-enters the workstation or reconnects the wrist strap to ground. Official certification and training for these people are also good practices for an ESD safe environment. Some recommended practices for insuring ESD safe environment are listed below.

5.1 Static-safe Workstation Requirements

ESD sensitive devices can be damaged by humans, machines, or a charged body. For example, plastic boxes and bags carry charges which can damage the LEDs. Therefore, a static-safe workstation should be provided whenever the LEDs are in an unprotected or vulnerable state (not in a closed Faraday cage). The workstation should never act as a storage area for any materials, including the LEDs. Workstations should also be free of static charge generators such as untreated page protectors, personal items, notebooks, and so forth. Agilent’s manufacturing specifications require static generators be at least 1 meter from ESD sensitive items. A work station can be fixed or movable.

5.1.1 Work Surface

The ideal surface is made from static dissipative materials constructed so that any charged device it contacts will be discharged slowly through the distributed resistance of the surface. A conductive surface isolated by a resistor is not recommended; conductive surfaces can absorb a discharge thus damaging the LEDs or causing short circuits in assemblies.

5.1.2 Grounding
An accessible grounded terminal or “banana plug” receptacle should be provided for connecting the workstation operator’s wrist strap device to ground. The resistance from the facility ESD ground to this terminal should not exceed two ohms. Wrist strap cords should be directly connected to the wrist strap. No other devices should be inserted into the ground cord’s path to ground, such as smocks or work surfaces.

5.1.3 Signs
A static attention sign should be displayed at each static-safe workstation and should be large enough to read 1 meter away from the workstation or work area. In addition, floor tape with black lettering on a yellow background should mark the perimeter of each static safe work area.

5.2 Antistatic Treatments and Ionization

Many insulators and static generators can be temporarily made safe with topical treatments. Existing topical antistatic chemicals will not affect the epoxy lens of InGaN LED. Static control on power sources greater than 500 volts can be accomplished by air ionization. Air ionization is a good idea whenever the LEDs are passed through machines. Creating a special environment is one of the best ways of promoting ESD consciousness. Ionizers are powerful tools in preventing ESD.

5.3 Wrist Strap Grounding

Personnel grounding for ESD damage prevention is achieved predominantly through the use of wrist strap devices; footwear grounding is not always required but provides additional protection from ESD. Every individual handling ESD sensitive items and who is not otherwise grounded, should be connected to ground via a wrist strap device. Wrist straps should be worn by persons handling ESD sensitive devices any time conductive flooring and footwear are not present. Wrist straps should also be worn while persons are seated (even if conductive flooring and footwear are being used). People tend to lift their feet and heels while seated, thus breaking the connection to ground. Frequent verification of the wrist strap’s resistance path to ground is recommended. Additionally, the path to ground should be checked each time an individual re-connects to ground (every time the workstation is entered or the banana plug is re-connected).

5.4 Clothing

Agilent’s specification for static charge on clothing states a charge shall not exceed 50 volts. This includes a person’s hair or facial hair.

6.0 Record Keeping

ESD procedures for individuals, any type of periodic testing, and auditing are highly recommended. Third party auditing may also be needed to identify deficiencies in the ESD safety procedures. Record keeping of such information is invaluable to improve such procedures and is generally required for compliance with ISO 9000.

7.0 Other Reference Materials for ESD Control

AT&T, *Electrostatic Discharge Control Handbook*, Select code 5000-000, Issue 3, 1989. (Available from: AT&T commercial Accounts, 1-800-432-6600.)

CENELEC Electronic Components Committee (CECC), “Protection of Electrostatic Sensitive Devices, Part 1, General Requirements”. Document EN 1-00015-1, July 1992

Dangelmayer, G. Theodore, *ESD Program Management*, New York: Van Nostrand Reinhold, 1980.

EOS/ESD Association Standards, New York. (Available from: ESD Association, 7902 Turin Rd., Suite 4, Rome, NY. 13440-2069, (315) 339-6937.)

Agilent Technologies, *General Semiconductor Specification*, Document No. A-5951-7600-1.

Agilent Technologies, *Workmanship Specification for ESD Control*, Document No. A-5951-1589-1.

McAteer, Owen J., *Electrostatic* Discharge Control, USA: McGraw-Hill, 1990.

MIL-HDBK-263A, *Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding Electrically initiated Explosive Devices)* (Metric). February 1991.

MIL-STD-1686A, *Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding Electrically Initiated Explosive Devices)* (Metric). 8 August 1988.

National Fire Protection Association, *Standard for Health Care Facilities.* ANSI/NFPA 99, 1990.

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Data subject to change.

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