Quantum Mechanics_Electrostatic discharge

Electrostatic discharge (**ESD**) is the sudden flow of electricity between two electrically charged objects caused by contact, an electrical short, ordielectric breakdown. A buildup of static electricity can be caused by tribocharging or by electrostatic induction. The ESD occurs when differently-charged objects are brought close together or when the dielectric between them breaks down, often creating a visible spark.

ESD can create spectacular electric sparks (lightning, with the accompanying sound of thunder, is a large-scale ESD event), but also less dramatic forms which may be neither seen nor heard, yet still be large enough to cause damage to sensitive electronic devices. Electric sparks require a field strength above approximately 4 kV/cm in air, as notably occurs in lightning strikes. Other forms of ESD include corona discharge from sharp electrodes andbrush discharge from blunt electrodes.

ESD can cause a range of harmful effects of importance in industry, including gas, fuel vapour and coal dust explosions, as well as failure of solid state electronics components such as integrated circuits. These can suffer permanent damage when subjected to high voltages. Electronics manufacturers therefore establish electrostatic protective areas free of static, using measures to prevent charging, such as avoiding highly charging materials and measures to remove static such as grounding human workers, providing antistatic devices, and controlling humidity.
ESD simulators may be used to test electronic devices, for example with a human body model or a charged device model.

Causes of ESD

One of the causes of ESD events is Static electricity. Static electricity is often generated through tribocharging, the separation of electric charges that occurs when two materials are brought into contact and then separated. Examples of tribocharging include walking on a rug, rubbing a plastic comb against dry hair, rubbing a balloon against a sweater, ascending from a fabric car seat, or removing some types of plastic packaging. In all these cases, the friction between two materials results in tribocharging, thus creating a difference of electrical potential that can lead to an ESD event.

Another cause of **ESD** damage is through electrostatic induction. This occurs when an electrically charged object is placed near a conductive object isolated from ground. The presence of the charged object creates an electrostatic field that causes electrical charges on the surface of the other object to redistribute. Even though the net electrostatic charge of the object has not changed, it now has regions of excess positive and negative charges. An ESD event may occur when the object comes into contact with a conductive path. For example, charged regions on the surfaces of styrofoam cups or bags can induce potential on nearby ESD sensitive components via electrostatic induction and an ESD event may occur if the component is touched with a metallic tool.

Types of ESD

The most spectacular form of ESD is the **spark**, which occurs when a heavy electric field creates an ionized conductive channel in air. This can cause minor discomfort to people, severe damage to electronic equipment, and fires and explosions if the air contains combustible gases or particles.

However, many ESD events occur without a visible or audible spark. A person carrying a relatively small electric charge may not feel a discharge that is sufficient to damage sensitive electronic components. Some devices may be damaged by discharges as small as 30V. These invisible forms of ESD can cause outright device failures, or less obvious forms of degradation that may affect the long term reliability and performance of electronic devices. The degradation in some devices may not become evident until well into their service life.[*citation needed*]

Sparks

Main article: electric spark

A spark is triggered when the Electric field strength exceeds approximately 4–30 kV/cm[1] — the dielectric field strength of air. This may cause a very rapid increase in the number of free electrons and ions in the air, temporarily causing the air to abruptly become an electrical conductor in a process called dielectric breakdown.

Lightning over Rymań. Northern Poland.

Perhaps the best known example of a natural spark is lightning. In this case theElectric potential between a cloud and ground, or between two clouds, is typically hundreds of millions of volts. The resulting current that cycles through the stroke channel causes an enormous transfer of energy. On a much smaller scale, sparks can form in air during electrostatic discharges from charged objects that are charged to as little as 380 V (Paschen's law).

Earth's atmosphere consists of 21% oxygen (O_2) and 78% nitrogen (N_2). During an electrostatic discharge, such as a lightning flash, the affected atmospheric molecules become electrically overstressed. The diatomic oxygen molecules are split, and then recombine to form ozone (O_3), which is unstable, or reacts with metals and organic matter. If the electrical stress is high enough, nitrogen oxides(NOx) can form. Both products are toxic to animals, and nitrogen oxides are essential for nitrogen fixation. Ozone attacks all organic matter by ozonolysis and is used in water purification.

Sparks are an ignition source in combustible environments that may lead to catastrophic explosions in concentrated fuel environments. Most explosions can be traced back to a tiny electrostatic discharge, whether it was an unexpected combustible fuel leak invading a known open air sparking device, or an unexpected spark in a known fuel rich environment. The end result is the same if oxygen is present and the three criteria of the fire triangle have been combined.

Corona discharge

Main article: corona discharge

A corona discharge is a relatively steady discharge which occurs between a highly curved electrode, for example the tip of a needle or a small diameter wire, and an electrode of low curvature such as a flat plate.[2] The high curvature produces a high potential gradient around one electrode, causing the intervening medium, often air, to break down and allow current to flow. The discharge may be a short-lived ESD event or, if drawing on an external power source, it may last indefinitely.

A brush discharge is a type of corona discharge which occurs between an electrode with a curvature between 5 mm and 50 mm and a voltage of about 500 kV/m.[3] The resulting discharge paths have the shape of a brush.

Damage prevention in electronics

A portion of a static discharger on an aircraft. Note the two sharp 3/8" metal micropoints and the protective yellow plastic.

Prevention of ESD bases on Electrostatic Protective Area (EPA). EPA can be a small working station or a large manufacturing area. The main principle of an EPA is that there are no highly charging materials in the vicinity of ESD sensitive electronics, all conductive materials are grounded, workers are grounded, and charge build-up on ESD sensitive electronics is prevented. International standards are used to define typical EPA and can be found for example from International Electrotechnical Commission (IEC) or American National Standards Institute(ANSI).

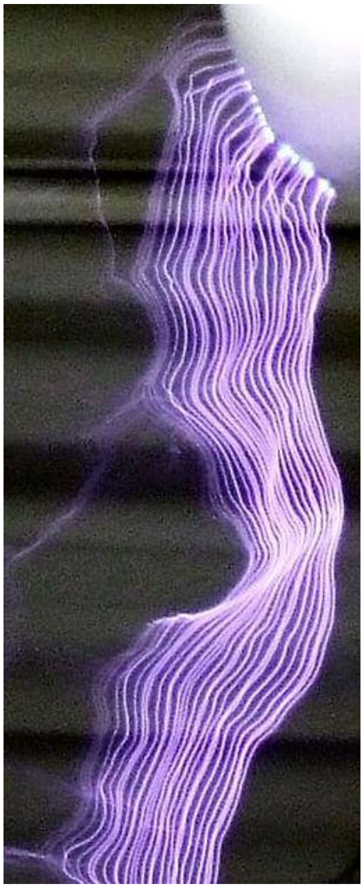
ESD prevention within an EPA may include using appropriate ESD-safe packing material, the use of conductive filaments on garments worn by assembly workers,conducting wrist straps and foot-straps to prevent high voltages from accumulating on workers' bodies, anti-static mats or conductive flooring materials to conduct harmful electric charges away from the work area, andhumidity control. Humid conditions prevent electrostatic charge generation because the thin layer of moisture that accumulates on most surfaces serves to dissipate electric charges.

Ion generators are sometimes used to inject ions into the ambient airstream. Ionization systems help to neutralize charged surface regions on insulative ordielectric materials. Insulating materials prone to triboelectric charging should be kept away from sensitive devices to prevent accidental charging of devices through induction. On aircraft, static dischargers are used on the trailing edges of wings and other surfaces.

Manufacturers and users of integrated circuits must take precautions to avoid ESD. ESD prevention can be part of the device itself and include special design techniques for device input and output pins. External protection components can also be used with circuit layout.

Due to dielectric nature of electronics component and assemblies, electrostatic charging can not be completely prevented during handling of devices. Most of ESD sensitive electronic assemblies and components are also so small that manufacturing and handling is done with automated equipment. ESD prevention activities are therefore important with those processes where components come into direct contact with equipment surfaces. In addition, it is important to prevent ESD when an electrostatic discharge sensitive component is connected with other conductive parts of the product itself. An efficient way to prevent ESD is to use materials that are not too conductive but will slowly conduct static charges away. These materials are called static dissipative and have resistivity values in the range of 10^5 to 10^{12} ohm-meters. Materials in automated manufacturing which will touch on conductive areas of ESD sensitive electronic should be made of dissipative material, and the dissipative material must be grounded.

Simulation and testing for electronic devices



Electric discharge showing the ribbon-like plasmafilaments from multiple discharges from a Tesla coil.

For testing the susceptibility of electronic devices to ESD from human contact, anESD Simulator with a special output circuit, called the human body model (HBM) is often used. This consists of a capacitor in series with a resistor. The capacitor is charged to a specified high voltage from an external source, and then suddenly discharged through the resistor into an electrical terminal of the device under test. One of the most widely used models is defined in the JEDEC 22-A114-B standard, which specifies a 100 picofarad capacitor and a 1500 ohm resistor. Other similar standards are MIL-STD-883 Method 3015, and the ESD Association's ESD STM5.1. For comportment to European Union standards for Information Technology Equipment, the IEC/EN 61000-4-2 test specification is used.[4]Guidelines and requirements are given for test cell geometries, generator specifications, test levels, discharge rate and waveform, types and points of discharge on the "victim" product, and functional criteria for gauging product survivability.

A Charged Device Model (CDM) test is used to define the ESD a device can withstand when the device itself has an electrostatic charge and discharges due to metal contact. This discharge type is the most common type of ESD in electronic devices and causes most of the ESD damages in their manufacturing. CDM discharge depends mainly on parasitic parameters of the discharge and strongly depends on size and type of component package. One of the most widely used CDM simulation test models is defined by the JEDEC.

Other standardized ESD test circuits include the following:

- Machine model (MM)
- Transmission line pulse (TLP).

References

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