# Whitepapers

**ESD Design Concerns in Automated Assembly Equipment**
**by Donn G. Bellmore, Universal Instruments**

## Introduction

Electrostatic discharge (ESD) has been a concern in the assembly of printed circuit boards for many years; however, not to the degree that is needed now with the advancements in solid state devices and automated assembly equipment. Conventional ESD controls are not enough. Much of the assembly equipment today processes 4,000 to 20,000 components per hour. Without proper design considerations, the automated equipment can generate large amounts of static charges and damage devices in large quantities in a short time. The selection of materials, fasteners, assembly methods, and proper grounding techniques has become extremely important in controlling the effects of ESD. This paper will discuss how ESD is generated, the dangers it presents, and methods to minimize the hazards of ESD in the assembly process.

## What is ESD?

ESD, simply stated, is the rapid equalization of charges. It costs the electronics industry billions of dollars every year. All substances are composed of atoms, which contain electrons and protons. As a substance gains or loses electrons, the electrical balance is altered to a positive or negative charge. Static electricity is the accumulation of positive or negative charges on the surfaces of either similar or dissimilar materials. The charge accumulation is usually caused by the contact and separation of materials or friction commonly referred to as triboelectric charging.

There are a number of factors that affect charge accumulation. Some of them are the degree of contact, the coefficient of friction, and the separation rate. The charge will continue to accumulate until the stimulus is stopped, the charge is drained off, or the charge reaches a level of sufficient strength to break down the dielectric strength or insulating properties of the surrounding materials. When the dielectric strength is overcome, the equalization of static charges is rapid. The rapid equalization of charges is referred to as an electrostatic discharge event or ESD. Due to the rapid discharge of voltages through a very small resistance, the equivalent current can be greater than 20 amps. If the discharge is through a device such as an integrated circuit (IC) or other ESD-sensitive component, the high current flow can cause severe damage to the circuitry designed to conduct micro- or milli-amperes.

There are several models used to describe how devices are damaged — the Human Body Model (HBM), the Machine Model (MM), the Charged Device Model (CDM), and the effect of electric fields on devices. Due to the nature of automated assembly equipment, the major concerns are the last three models or modes of damage. They will each be discussed briefly.

## Machine Model or Mode

Automated assembly equipment uses tracks, conveyor belts, slides, component handlers, and other items to move and guide the devices in the desired direction of the process. If the equipment is not designed properly, conveyors and handling systems can accumulate significant charges that can discharge through the devices during the processing. When the machine components discharge through a device, it is called Machine Model Mode and is modeled with the Machine Model.

## Charged Device Model or Mode

If, for any reason, a device has accumulated a charge and it is placed in contact with a surface with a lesser charge, the charge will dissipate through a conductor on the device. When the device discharges to another material, it is called a Charge Device Mode and is modeled using the Charged Device Model.

## Influence or Electric Fields (E Fields)

Induction can cause potential differences between resistive pathways of IC, which can cause dielectric breakdown of the insulators. Another mechanism of failure is that the charge on a device, when introduced to a field, will polarize. When the charge polarizes, a difference of potential is created and can discharge to an opposite charge, thus allowing for two discharges or equalization events. In controlling ESD, materials with different resistive properties are used. These same materials can be used in automatic assembly equipment to obtain the desired results. The nomenclature used to specify the resistive attribute of the material is usually surface or volume resistivity.

**Surface Resistivity**
A brief explanation of surface resistivity is a value obtained by measuring resistance between two electrodes placed on the same surface. The geometry of the electrodes and the resistance values are combined through calculations to obtain ohms per square. Meters are available and calibrated to display ohm per square.

**Volume Resistivity**
Volume resistivity is the resistance of a material through its thickness. The units of measure is ohms centimeter or ohms inch.

**Conductive Materials**
Conductive materials are materials with surface or volume resistivity less than 106 ohms per square or ohms centimeter, respectively.

**Dissipative Materials**
Dissipative materials have a surface or volume resistance less than 1012 ohms per square or ohms centimeter, respectively.

**Antistatic Material**
"Antistatic" refers to a material property that inhibits charge accumulation. Either a substance is added to the material during the manufacturing process or it is topically applied. Antistatic materials do not necessarily correlate to surface or volume resistance.

**Conductive Additives and Films**
When plastic materials or composites are the only solution, due to economy or other design reasons, there are additives, that when mixed into the plastic matrix, achieve conductivity or dissipative qualities based on the percentage of additive to resin.

Fibers that add conductive or dissipative qualities to the resin and also reinforce the resin are either conductive by themselves or by surface plating. While the fibers achieve the desired conductivity or dissipative qualities and added strength, they also change shrinkage and brittleness factors.

Fillers, which providing dissipative and conductive qualities, usually reduce the strength of the base resin while increasing stiffness.

**Table 1 Conductive Additives**

| Reinforcements | Fillers |
|---|---|
| Pan Carbon Fibers | Carbon Powder |
| Pitch Carbon Fibers | Metal Powder |
| Ni-Plated Carbon Fibers | Aluminum Flakes |
| Aluminum Fibers | Organic Antistats |
| Stainless Steel Fibers | |
| Metalized Glass Fibers | |

(Some of the reinforcements and fillers available for improved composites conductivity.)

**Conveyor Belts**
Conveyor belts used to transport components, PC boards, and other devices, made out of plastics, fabrics, or rubber, should be made of a dissipative material if they are to receive devices from another part of the machine. If the belts are conductive 100 to 106 ohms per square, they might discharge a charged device too quickly, causing damage to the device. At a resistance range of 106 to 109 ohms per square, the belts should not charge up if they are properly grounded through idler wheels and pulleys into the frame.

Another concern is the speed of the conveyors. If the belt moves too fast, allowing a device to skip or slide when fed onto the belts, or if the device is held in place while the belt continues to move, triboelectric charging can occur. The belt will dissipate the charge if grounded; however, the device or PC board will retain the charge, creating a hazard.

**Guides and Tracks**
Guides and tracks used to provide a pathway or hold devices in a certain place or position should be made out of a material that will dissipate a charge and inhibit triboelectric charging of the device. Materials with a surface resistivity of 106 ohms per square will allow dissipation without damaging the device. If the devices are introduced in a static-free condition, conductive (up to 106 ohms per square) materials can be used.

**Technical Supplement**
Do not use aluminum with an anodized finish. The anodization acts as an insulator and will add significantly to triboelectric charging of the device. Electroless nickel, titanium nitride, or even zinc plating will help prevent triboelectric charging of the devices. Guides and tracks should also maintain the position of ICs to a confined orientation. For example, if an IC is placed on a conveyor with the leads up, it accumulates a charge and, if it is flipped over for further processing, the change of position can alter the capacitance of the device. If the charge is large enough, changing the capacitance may cause the device to discharge.

Trays made out of plastics and other composites should have a surface or volume resistivity less than 109 ohms per square and ohms centimeter. With resistivities less than 109 ohms per square or centimeter, charges will be dissipated as they are created, thereby preventing a charge buildup if the platform or holding assembly is properly grounded. If a charged device has to be dropped, slid, or placed on a conductive surface, the charged device could discharge to the surface. This is an example of the charged device mode of failure.

Covers, when in close proximity to the board or component flow (less than 24"), should be in the dissipative range. If it is a plastic transparent cover, use dissipative transparent material; a painted cover should be painted with a conductive or dissipative paint to prevent strong fields due to triboelectric charging.

Device grippers and nozzles should be fabricated out of dissipative materials (between 106 and 109 ohms per square) and should have a good path to ground; otherwise, the charged device and the machine modes of failure can occur.

In applications where voltage levels less than 50 volts are desired, the assemblies should contain materials with resistivities less than 106 ohms per square and greater than 103 ohms per square; however, the devices entering the process will have to be free of significant charges, otherwise they may be damaged.

Coatings, such as black oxide and anodizing, render metal surfaces as insulators, while zinc plating and electroless nickel chromate maintain the surface resistivity at a very conductive level and provide corrosion resistance, as well as cosmetic appearance.

Items such as Phenolic, Delrin (black or white), Nylon, Ultem, and UHMW in their natural states, should not be used as pathways, guides, or as conveyor belt guides or rails when ESD-sensitive devices are being handled.

Table 2 provides a brief list of coatings with high resistances that should not be used and coatings with low resistances that should be used in close proximity to device pathways.

**Table 2 Commonly Used Coatings**

| High Resistance | Low Resistance |
|---|---|
| Anodize (or any color) | Zinc (natural or black) |
| Black Oxide | Electroless Nickel |
| Aluminum Oxide (uncoated) | Titanium Nitride |
| Polylube | Conductive Paints |
| Teflon Coating | Graphite Paints |

**Path to Ground**

There has to be a grounding path for an accumulated charge to dissipate. A conductor, when isolated, will accumulate a charge. A conductive conveyor belt will accumulate a charge if there is not sufficient ground connection to dissipate the charge. Dissipative plastic covers will accumulate a charge if the hinges do not provide a sufficient ground path.

Conductive or dissipative conveyor belts can be connected to ground through conductive rollers, idlers, and guides that are connected directly to ground. It is important to mention that belts with low surface resistivity and high volume resistivity require grounding of both surfaces. If the conveyor belt has a low volume resistivity, only one surface requires grounding and both surfaces will dissipate to ground.

Mating surfaces of mechanical assemblies should be either naturally conductive or plated. If the design does not permit a conductive coating, then braided ground straps should be installed across both members. In situations where assemblies such as options attach to the main portion of the machine, ground connections are important to maintain equal potential across the entire machine. Braided grounding straps to the main frame of the machine should be used when positive mechanical connections are not possible.

Safety ground wires should not be used in place of ground straps. Braided ground straps have a greater surface area that will allow a greater charge dissipation and because of the braided straps, E fields are minimized.

Items such as ball slides and some ball bearings can act as isolators and may require a ground strap to provide continuity to ground.

Hinges can become corroded and act as an insulator or a large resistor in the ground path, therefore, dissipating covers mounted in frames and with hinges may require braided ground straps to provide continuity around the hinge to ground.

**Assembly Methods**

Bearings, when pressed into an anodized plated hole, will not provide a good path to ground. The hole should be bare metal or broken anodized coating.

Clean roller bearing and cross roller slides, under a slight preload, will usually provide a path to ground even with a light lubrication.

Painted or anodized panels in close proximity to device paths should be mounted using internal tooth star washers and zinc-plated screws to provide continuity between panels.

Plastic covers are usually installed in a frame by using a rubber gasket between the cover and the frame, which is compressed slightly when fully installed. When using dissipative plastic covers, provision to provide a connection to the frame is required. Dissipative rubber gasket material or zinc screws, ground straps, or copper clips can be used to connect the plastic panel to the frame.