Fundamentals of Electrostatic Discharge

Part Three--Basic ESD Control Procedures and Materials

In Part Two, *Principles of ESD Control* we introduced four principles of static control and nine key elements of ESD program development and implementation. In Part Three, we will cover some of the primary specific static control procedures and materials that become part of your program. First, a quick review.

Basic Principles of Static Control

We suggested focusing on just six basic principles in the development and implementation of effective ESD control programs:

Design in immunity by designing products and assemblies to be as immune as reasonable from the effects of ESD.

Define the level of control needed in your environment.

Identify and define the electrostatic protected areas (EPA), the areas in which you will be handling sensitive parts.

Eliminate and reduce generation by reducing and eliminating static generating processes, keeping processes and materials at the same electrostatic potential, and by providing appropriate ground paths to reduce charge generation and accumulation.

Dissipate and neutralize by grounding, ionization, and the use of conductive and dissipative static control materials.

Protect products from ESD with proper grounding or shunting and the use of static control packaging and materials handling products.

At the facility level our static control efforts concentrate on the last five principles. In this column we will concentrate on the primary materials and procedures that eliminate and reduce generation, dissipate and neutralize charges, or protect sensitive products from ESD.

Identifying the Problem Areas and the Level of Control

One of the first questions we need to answer is "How sensitive are the parts and assemblies we are manufacturing or handling?" This information will guide you in determining the various procedures and materials required to control ESD in your environment.

How do you determine the sensitivity of your parts and assemblies or where can you get information about their ESD sensitivity? A first source would be the manufacturer or supplier of the component itself. An additional source is ITT Research Institute/Reliability Analysis Center in Rome, NY, which publishes ESD susceptibility data for 22,000 devices, including microcircuits. You may find that you need to have your specific parts tested for ESD sensitivity. We will discuss device sensitivity testing in part 5 of this series.

The second question you need to answer is "Which areas of our facility need ESD protection?" This will allow to define your specific electrostatic protected areas (EPAs), the areas in which you will be handling sensitive parts and the areas in which you will need to bond or electrically connect all conductive and dissipative materials, including personnel, to a known ground. Often you will find that there are more areas that require protection than you originally thought, usually wherever ESDS devices are handled. Typical areas requiring ESD protection are shown in Table 1.

Table 1 Typical Facility Areas Requiring ESD Protection
Receiving
Inspection
Stores and warehouses
Assembly
Test and inspection
Research and development
Packaging
Field service repair
Offices and laboratories
Clean rooms

Grounding

Throughout our discussion, we will see how important grounding is to effective ESD control. Effective ESD grounds are of critical importance in any operation, and ESD grounding should be clearly defined and regularly evaluated.

A primary means of protecting of ESD susceptible (ESDS) items is to provide a ground path to bring ESD protective materials and personnel to the same electrical potential. All conductors in the environment, including personnel, must be bonded or electrically connected and attached to a known ground or contrived ground, creating an equipotential balance between all items and personnel. Electrostatic protection can be maintained at a potential above a "zero" voltage ground reference as long as all items in the system are at the same potential. It is important to note that non-conductors in an Electrostatic Protected Area (EPA) cannot lose their electrostatic charge by attachment to ground

ESD Association Standard ANSI EOS/ESD 6.1-*Grounding* recommends a two-step procedure for grounding ESD protective equipment.

The first step is to ground all components of the work area (worksurfaces, people, equipment, etc.) to the same electrical ground point called the “common point ground.” This common point ground is defined as a “system or method for connecting two or more grounding conductors to the same electrical potential.”

Figure 1--Common Point Ground Symbol

This ESD common point ground should be properly identified. ESD Association standard EOS/ESD S8.1-1993 recommends the use of the symbol in Figure 2 to identify the common point ground.

The second step is to connect the common point ground to the equipment ground or the third wire (green) electrical ground connection. This is the preferred ground connection because all electrical equipment at the workstation is already connected to this ground. Connecting the ESD control materials or equipment to the equipment ground brings all components of the workstation to the same electrical potential. If a soldering iron used to repair an ESDS item were connected to the electrical ground and the surface containing the ESDS item were connected to an auxiliary ground, a difference in electrical potential could exist between the iron and the ESDS item. This difference in potential could cause damage to the item.

Any auxiliary grounds (water pipe, building frame, ground stake) present and used at the workstation must be bonded to the equipment ground to minimize differences in potential between the two grounds.

Detailed information on ESD grounding can be found in ESD Association standard ESD-S6.1, Grounding-Recommended Practices.

Controlling Static on Personnel and Moving Equipment

In many facilities, people are one of the prime generators of static electricity. The simple act of walking around or repairing a board can generate several thousand volts on the human body. If not properly controlled, this static charge can easily discharge into a static sensitive device—a human body model (HBM) discharge.

Even in highly automated assembly and test processes, people still handle static sensitive devices…in the warehouse, in repair, in the lab, in transport. For this reason, static control programs place considerable emphasis on controlling personnel generated electrostatic discharge. Similarly, the movement of carts and other wheeled equipment through the facility also can generate static charges that can transfer to the products being transported on this equipment.

Wrist Straps

Typically, wrist straps are the primary means of controlling static charge on personnel. When properly worn and connected to ground, a wrist strap keeps the person wearing it near ground potential. Because the person and other grounded objects in the work area are at or near the same potential, there can be no hazardous discharge between them. In addition, static charges are safely dissipated from the person to ground and do not accumulate.

Wrist straps have two major components, the cuff that goes around the person's wrist and the ground cord that connects the cuff to the common point ground. Most wrist straps have a current limiting resistor molded into the ground cord head on the end that connects to the cuff. The resistor most commonly used is a one megohm, 1/4 watt with a working voltage rating of 250 volts.

Wrist straps should be tested on a regular basis. Daily testing or continuous monitoring is recommended.

Floors, Floor Mats, Floor Finishes

A second method of controlling electrostatic charge on personnel is with the use of ESD protective floors in conjunction with ESD control footwear or foot straps. This combination of floor materials and footwear provides a ground path for the dissipation of electrostatic charge, thus reducing the charge accumulation on personnel and other objects to safe levels. In addition to dissipating charge, some floor materials (and floor finishes) also reduce triboelectric charging. The use of floor materials is especially appropriate in those areas where increased personnel mobility is necessary. In addition, floor materials can minimize charge accumulation on chairs, carts, lift trucks and other objects that move across the floor. However, those items require dissipative or conductive casters or wheels to make electrical contact with the floor. When used as the primary personnel grounding system, the resistance to ground including the person, footwear and floor must be the same as specified for wrist straps (< 35 x 10E6 ohms) or the voltage accumulation on a person must be less than 100 volts.

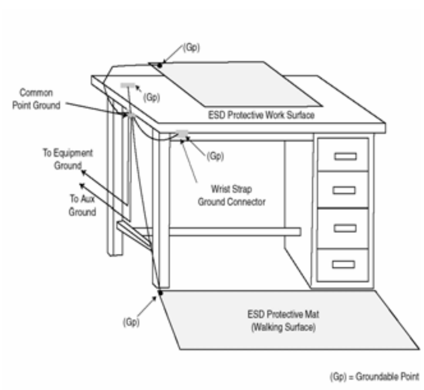
Shoes, Grounders, Casters

Used in combination with ESD protective floor materials, static control shoes, grounders, casters and wheels provide the necessary electrical contact between the person or object and the floor material. Insulative footwear, casters, or wheels prevent static charges from flowing from the body to the floor to ground.

Clothing

Clothing is a consideration in some ESD protective areas, especially in clean rooms and very dry environments. Clothing materials can generate electrostatic charges that may discharge into sensitive components or they may create electrostatic fields that may induce charges on the human body. Because clothing usually is electrically insulated or isolated from the body, charges on clothing fabrics are not necessarily dissipated to the skin and then to ground. Grounded static control garments are intended to minimize the effects of electrostatic fields or charges that may be present on a person’s clothing.

Figure 2--Typical ESD Workstation



Workstations and Worksurfaces

An ESD protective workstation refers to the work area of a single individual that is constructed and equipped with materials and equipment to limit damage to ESD sensitive items. It may be a stand-alone station in a stockroom, warehouse, or assembly area, or in a field location such as a computer bay in commercial aircraft. A workstation also may be located in a controlled area such as a clean room. The key ESD control elements comprising most workstations are a static dissipative worksurface, a means of grounding personnel (usually a wrist strap), a common grounding connection, and appropriate signage and labeling. A typical workstation is shown in Figure 3.

The workstation provides a means for connecting all worksurfaces, fixtures, handling equipment, and grounding devices to a common point ground. In addition, there may be provision for connecting additional personal grounding devices, equipment, and accessories such as constant ground monitors and ionizers.

Static protective worksurfaces with a resistance to ground of 10^6 to 10^9 provide a surface that is at the same electrical potential as other ESD protective items in the workstation. They also provide an electrical path to ground for the controlled dissipation of any static potentials on materials that contact the surface. The worksurface also helps define a specific work area in which ESD sensitive devices may be safely handled. The worksurface is connected to the common point ground.

Production Equipment and Production Aids

Although personnel generated static is usually the primary ESD culprit in many environments, automated manufacturing and test equipment also can pose an ESD problem. For example, a device may become charged from sliding down a feeder. If the device then contacts the insertion head or another conductive surface, a rapid discharge occurs from the device to the metal object--a Charged Device Model (CDM) event. In addition, various production aids such as hand tools, tapes, or solvents also be ESD concerns,

Grounding is the primary means of controlling static charge on equipment and many production aids. Much electrical equipment is required by the National Electrical Code to be connected to the equipment ground (the green wire) in order to carry fault currents. This ground connection also will function for ESD purposes. All electrical tools and equipment used to process ESD sensitive hardware require the 3 prong grounded type AC plug. Hand tools that are not electrically powered, i.e., pliers, wire cutters, and tweezers, are usually grounded through the ESD worksurface and the (grounded) person using the conductive tools. Holding fixtures should be made of conductive or static dissipative materials when possible. A separate ground wire may be required for conductive fixtures not sitting on an ESD worksurface or handled by a grounded person. For those items that are composed of insulative materials, the use of ionization or application of topical antistats may be required to control generation and accumulation of static charges.

Packaging and Handling

Direct protection of ESDS devices from electrostatic discharge is provided by packaging materials such as bags, corrugated, and rigid or semi-rigid packages. The primary use of these items is to protect the product when it leaves the facility, usually when shipped to a customer. In addition, materials handling products such as tote boxes and other containers primarily provide protection during inter or intra facility transport.

The main ESD function of these packaging and materials handling products is to limit the possible impact of ESD from triboelectric charge generation, direct discharge, and electrostatic fields. The initial consideration is to have low charging materials in contact with ESD sensitive items. For example, the low charging property would control triboelectric charge resulting from sliding a board or component into the package or container. A second requirement is that the material provides protection from direct electrostatic discharge as well as shield from electrostatic fields.

Many materials are available that provide all three benefits: low charging, discharge protection, and electric field suppression. The inside of these packaging materials have a low charging layer, but also have an outer layer with a surface resistance generally in the dissipative range.

Resistance or resistivity measurements help define the material’s ability to provide electrostatic shielding or charge dissipation. Electrostatic shielding attenuates electrostatic fields on the surface of a package in order to prevent a difference in electrical potential from existing inside the package. Electrostatic shielding is provided by materials that have a surface resistance equal to or less than 1.0×10^3 when tested according to EOS/ESD-S11.11 or a volume resistivity of equal to or less than 1.0×10^3 ohm-cm when tested according to the methods of EIA 541. In addition, shielding may be provided by packaging materials that provide an air gap between the package and the product. Dissipative materials provide charge dissipation characteristics. These materials have a surface resistance greater than 1.0×10^4 but less than or equal to 1.0×10^{11} when tested according to EOS/ESD-S11.11 or a volume resistivity greater than 1.0×10^5 ohm-cm but less than or equal to 1.0×10^{12} ohm-cm when tested according to the methods of EIA 541. ***ESD 11.31 on shield bags should be listed here as a way to measure ESD Discharge for bags.***

A material's low charging properties are not necessarily predicted by its resistance or resistivity.

Ionization

However, most static control programs also deal with isolated conductors that cannot be grounded, insulating materials (e.g., most common plastics). Topical antistats often are used to dissipate static charges from these items under some circumstances

More frequently, however, air ionization can neutralize the static charge on insulated and isolated objects by charging the molecules of the gases of the surrounding air. Whatever static charge is present on objects in the work environment will be neutralized by attracting opposite polarity charges from the air. Because it uses only the air that is already present in the work environment, air ionization may be employed even in clean rooms where chemical sprays and some static dissipative materials are not usable.

Air ionization is one component of a complete static control program, not necessarily a substitute for grounding or other methods. Ionizers are used when it is not possible to properly ground everything and as backup to other static control methods. In clean rooms, air ionization may be one of the few methods of static control available.

Cleanrooms

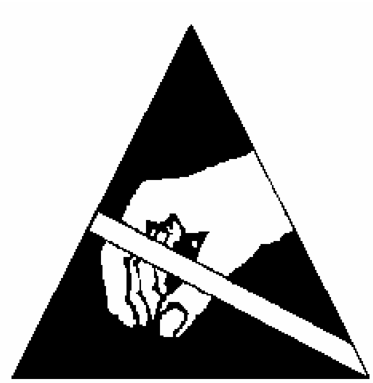
While the basic methods of static control discussed here are applicable in most environments, cleanroom manufacturing processes require special considerations.

Many objects integral to the semiconductor manufacturing process (quartz, glass, plastic, and ceramic) are inherently charge generating. Because these materials are insulators, this charge cannot be removed easily by grounding. Many static control materials contain carbon particles or surfactant additives that sometimes restrict their use in clean rooms. The need for personnel mobility and the use of clean room garments often make the use of wrist straps difficult. In these circumstances, ionization and flooring/footwear systems become key weapons against static charge.

Identification

A final element in our static control program is the use of appropriate symbols to identify static sensitive devices and assemblies, as well as products intended to control ESD. The two most widely accepted symbols for identifying ESDS parts or ESD control materials are defined in ESD Association *Standard ANSI ESD S8.1-1993 — ESD Awareness Symbols*.

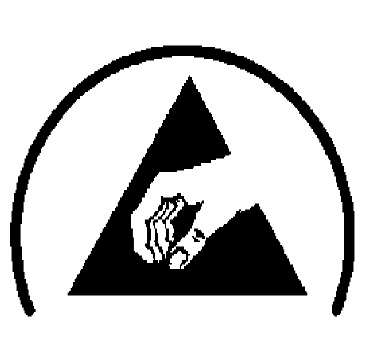
Figure 3--ESD Susceptibility Symbol



The ESD Susceptibility Symbol (Figure 3) consists of a triangle, a reaching hand, and a slash through the reaching hand. The triangle means “caution” and the slash through the reaching hand means “Don’t touch.” Because of its broad usage, the hand in the triangle has become associated with ESD and the symbol literally translates to “ESD sensitive stuff, don’t touch.”

The ESD Susceptibility Symbol is applied directly to integrated circuits, boards, and assemblies that are static sensitive. It indicates that handling or use of this item may result in damage from ESD if proper precautions are not taken. If desired, the sensitivity level of the item may be added to the label.

Figure 4--
ESD Protective Symbol



The ESD Protective Symbol (Figure 4) consists of the reaching hand in the triangle. An arc around the triangle replaces the slash. This “umbrella” means protection. The symbol indicates ESD protective material. It is applied to mats, chairs, wrist straps, garments, packaging, and other items that provide ESD protection. It also may be used on equipment such as hand tools, conveyor belts, or automated handlers that is especially designed or modified to provide ESD control.

Neither symbol is applied on ESD test equipment, footwear checkers, wrist strap testers, resistance or resistivity meters or similar items that are used for ESD purposes, but which do not provide actual protection.

Summary

Effective static control programs require a variety of procedures and materials. In this column, we have provided a brief overview of the most commonly used elements of a program. Additional in-depth discussion of individual materials and procedures can be found in publications such as the ESD Handbook published by the ESD Association.

Your program is up and running. How do you determine whether it is effective? How do you make sure your employees follow it? In Part 4, we will cover the topics of Auditing and Training.

For Additional Information

ESD Association Standards

ESD S1.1-1998: Evaluation, Acceptance, and Functional Testing of Wrist Straps, ESD Association, Rome, NY 13440

ESD STM2.1-1997: Resistance Test Method for Electrostatic Discharge Protective Garments, ESD Association, Rome, NY 13440

ESD STM3.1-2000: Ionization, ESD Association, Rome, NY 13440

ESD SP3.3-2000: Periodic Verification of Air Ionizers, ESD Association, Rome, NY 13440

ESD S4.1-1997 (Revised): Worksurfaces--Resistance Measurements, ESD Association, Rome, NY 13440

ESD STM4.2-1998: Worksurfaces - Charge Dissipation Characteristics, ESD Association, Rome, NY 13440

ESD S6.1-1999: Grounding -- Recommended Practice, ESD Association, Rome, NY 13440

ANSI ESD S7.1-1994: Floor Materials -- Resistive Characterization of Materials, ESD Association, Rome, NY 13440

ANSI ESD S8.1-1993: ESD Awareness Symbols, ESD Association, Rome, NY 13440

ESD S9.1-1995: Resistive Characterization of Footwear, ESD Association, Rome, NY 13440

ESD SP10.1-2000: Automated Handling Equipment, ESD Association, Rome, NY 13440

ANSI ESD S11.11-1993: Surface Resistance Measurement of Static Dissipative Planar ESD, ESD Association, Rome, NY 13440

ESD STM11.12-2000: Volume Resistance Measurement of Static Dissipative Planar Materials, ESD Association, Rome, NY 13440

ANSI ESD S11.31-1994: Evaluating the Performance of Electrostatic Discharge Shielding Bags, ESD Association, Rome, NY 13440

ESD STM12.1-1997: Seating-Resistive Characterization, ESD Association, Rome, NY 13440

ESD STM13.1-2000: Electrical Soldering/Desoldering Hand Tools, ESD Association, Rome, NY 13440

ANSI ESD S20.20-1999: Standard for the Development of an ESD Control Program, ESD Association, Rome, NY 13440

ESD STM97.1-1999: Floor Materials and Footwear -- Resistance in Combination with a Person, ESD Association, Rome, NY 13440

ESD STM97.2-1999 Floor Materials and Footwear Voltage Measurement in Combination with a Person, ESD Association, Rome, NY 13440

ESD ADV3.2-1995: Selection and Acceptance of Air Ionizers, ESD Association, Rome, NY 13440

ESD ADV53.1-1995: ESD Protective Workstations, ESD Association, Rome, NY 13440

ESD TR 20.20: ESD Handbook, ESD Association, Rome, NY 13440

Other Resources

IIT Research Institute / Reliability Analysis Center, 201 Mill Street, Rome, NY 13440-6916

ANSI/IEEE STD142, *IEEE Green Book*, Institute of Electrical and Electronics Engineers

ANSI/NFPA 70, National Electrical Code, Quincy, MA

National Fire Protection Association, Quincy, MA

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