Process Monitoring to Determine Electrostatic Risks

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Abstract. Designing a factory electrostatic discharge (ESD) control program requires an understanding of all the processes where unprotected ESD susceptible items are handled either manually or by machine. Human handling aspects are generally understood and control procedures where people are involved are commonly implemented with great care. Personnel grounding systems, monitors, and the like, are installed in order to make sure that personnel do not accumulate and transfer electrostatic charge that could damage sensitive parts during handling or assembly operations. However, the ability to determine what is occurring inside of process equipment has not been particularly easy up to now. Equipment is now available that allows the measurement and recording of electrical field information inside of many process tools. One of the goals of this work is to be able to characterize equipment as capable of handling parts susceptible to specific levels that may be related to component part sensitivity.

1. Background and Introduction:

The ESD Association in the United States published an ESD Technology Road Map \cite{1} in 2005. The Roadmap, prepared by leading electronic device designers from Intel, Texas Instruments and IBM, predicts a dramatic reduction in the designer’s ability to provide on-chip protection from electrical overstress (EOS) and electrostatic discharge (ESD), due to shrinking device geometries and ever increasing demand for performance. Predictions state that by the year 2010, electronic components will be in common usage with Human Body Model (HBM) sensitivity <100 volts. Machine Model (MM) sensitivity level predictions in the Road Map are <10 volts. Charged Device Model (CDM) failure levels are predicted at <50 volts for the most advanced products. These predictions place a new and intense burden on those manufacturing groups that have to handle these very sensitive parts.

Managing manufacturing processes to control EOS and ESD requires establishing a Control Program Plan that is auditable and verifiable. ANSI/ESD S20.20 \cite{2} and the soon to be released IEC 61340-5-1\cite{3} revision provide a suitable methodology for preparing, implementing, maintaining and verifying a consistent ESD Control Program.

1.1 Introduction to Process Measurement

A major element in any ESD Control Program is to provide the materials and equipment required to maintain personnel at a specified electrical resistance to ground (earth). It has been shown experimentally that a person with a resistance to ground of \(<3.5 \times 10^7 \ \Omega\), cannot generate more than 100 volts, even with very vigorous movement. Should components enter the manufacturing process...
with known sensitivity <100 volts HBM, then additional precautions are needed. For example, the disk drive manufacturing industry must deal with parts that are known to be very sensitive, certainly in the 5 volts to 10 volts HBM range, so their industry standard is set at <1 × 10^7 Ω for personnel resistance to ground to ensure that personnel are maintained at or near 10 volts.

If a component is grounded in the presence of an electrical field, a charge will be induced onto the component. Any subsequent contact with the component will lead to a discharge. Multiple charging – discharging events are often found in situations where uncontrolled electrical fields are allowed inside of process equipment. Electrical field measurement in and around equipment is needed in order to ensure that processes are not going to cause damage to susceptible parts. A goal of this type of measurement is to establish a process capability level for each piece of equipment or tool where parts are handled.

2. Equipment for Process Capability Measurements

Small, portable, electric field measurement devices and instruments (meters) have been available for many years. Being able to record electrical field data remotely, without wires or extension devices, is a new advance in the industry. Installing an electrical field meter on a circuit board, panel or other supporting device that is going through a process is the first step. The field meter is mounted to a fixture so the meter’s sensing device is the appropriate distance from an electrically isolated metal plate that will respond to electrical fields in the near-by environment.

The recording device is installed on the supporting device near the field meter to record the analog signal from the field meter. Once the supporting device is retrieved from the process, the stored information is downloaded to a computer where the data is analyzed and statistical calculations applied. Examples of installation on two supporting devices are shown in figures 1 and 2.

3. Procedures Involved in Process Monitoring

It is important to set-up a measurement procedure for data collection that accurately follows the actual processes where ESD susceptible items are handled. All of the normal operations should be involved as long as they are within the capability of the instruments. The most important activities, such as where components are installed on substrates, are generally considered the most likely for charge generation and discharge in automated processes. These processes include pick-and-place equipment,
manual assembly, and other semi-automated processes where connectors, components, devices, wires and other items are inserted into or placed onto a substrate.

External process measurements should be made to evaluate the overall conditions of the process environment before conducting the internal process monitoring measurements. All of the personnel part handling operations must be evaluated to ensure personnel are properly attached electrically to ground (earth) in any process area where unprotected parts are present. Figure 3 shows the voltage on a person wearing shoe grounding straps walking across three different floor surfaces. Bare concrete shows a small negative voltage generation in this example. Walking on an insulated cushioned mat, while certainly ergonomically comfortable, resulted in fairly high levels of voltage. Stepping onto a grounded, dissipative mat reduced the voltage to a reasonable level while also reducing the generation level. The small peak observed between the dissipative mat and the concrete is because of body capacitance changes during the process of stepping off of the mat onto the concrete.

![Figure 3. Voltage generation by a person walking across three different flooring surfaces](image)

**4. Measurement Results**

Figure 4 shows the results obtained from sending the measurement equipment mounted to the panel shown in Figure 1 through a semi-automated process before employing any electrostatic charge mitigation techniques. A piece of polyester backed tape is placed on the panel in the first station resulting in a large voltage spike. At the 2nd station a large condenser and other non-electronic parts were installed with a small resulting voltage observed on the field meter. A populated circuit board was inserted and bolted in place at the 3rd station and a wire harness and cable tie attached at station 4, each with somewhat larger pulses. Other processes at stations 5 and 6 also resulted in noticeable changes in the electrical field measurement.

Figure 5 is the same process as shown in Figure 4 after grounding several previously isolated process elements as well as the personnel during critical operations. There was considerable difference in voltage levels recorded between the two iterations.
4.1 Additional Results

A very interesting set of measurements has been made in a cleanroom operation that employs a large number of pulsed DC ionization devices. The results show the great importance of grounding all conductive materials while under the influence of pulsed ionization. Figure 6 shows the measured voltage swing from the pulsed DC ionization system. This level of voltage swing is considered normal for this type of installation whose primary purpose is to aid in cleaning particles out of the air. Under the influence of these ionizers, ungrounded conductors follow the voltage swings. If the ungrounded conductors are grounded while under the influence of these ionizers, a discharge will occur. Depending on the circumstances and applications, this discharge could harm susceptible parts if they are involved directly in the discharge.

Ungrounded personnel respond to the electrical field from the ionizers as shown in Figure 7. The person in the example wore a complete body covering “bunny suit” suitable for very clean operations but the resistance to ground of the garment and person was on the order of $10^9$ ohms through the floor. The voltage oscillation follows the ionizer swings but the level measured on the person is increased due to triboelectric charging during the walking motions.
In Figure 8, the voltage level on a metal cart, a grounded person (walking) and an ungrounded person (walking) are recorded. This figure shows the importance of grounding conductive objects in the ESD controlled work environment. In order to study the impact of grounding, each segment within the figure is analyzed separately to determine the maximum potential for each element and situation.

![Figure 8. Metal cart, grounded and ungrounded personnel under the influence of a pulsed DC ionizer](image)

Figure 9 is the probability analysis of the grounded person and Figure 10 is for the ungrounded person (from Figure 8). The grounded person in Figure 9 has a statistical mean observed voltage of about 75 volts (50% level). This analysis shows that the grounding of the person in the established environment, under the influence of a pulsed DC ionizer, results in a control level right around 100 volts. On the other hand, the analysis of the ungrounded person in Figure 10 shows a statistical mean of 1100 volts (50% level). The 10% risk level is about 1800 volts in this case. This would not represent a good condition in which to handle sensitive parts.

![Figure 9. Maximum voltage probability – grounded person](image)
5. Summary

The ESD Association’s *ESD Technology Road Map* predicts that electronic parts will become significantly more sensitive to all the various device testing regimes due to increased demands on performance. The factories that build equipment from these increasingly more sensitive parts will have to improve processes and reduce electrostatic hazards in order to reduce the likelihood of damage. Being able to predict, with certainty, the device sensitivity level that a process is capable of handling is an important step forward in manufacturing the ever changing myriad of electronic products. Tools are available now that allow the detailed investigation, recording, and analysis of electrostatic risks in a variety of process environments.

6. References

[1] ESD Association, 7900 Turin Road, Building 3, Rome, New York, USA 13440-2069, [www.esda.org](http://www.esda.org)
[2] ANSI/ESD S20.20 – *ESD Association Standard for the Development of an Electrostatic Discharge Control Program for the Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)*, ESD Association, 7900 Turin Road, Building 3, Rome, New York, USA 13440-2069, [www.esda.org](http://www.esda.org)
[3] IEC 61340-5-1 – *Protection of electronic devices from electrostatic phenomena – General Requirements*
[4] SH&A/Prostat Model PGA Autoanalysis System, 1072 Tower Lane, Bensenville, Illinois, USA 60106, [www.prostatcorp.com](http://www.prostatcorp.com)