

ESD SOLUTIONS FOR A CLASS Ø FACILITY

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Abstract

Expensive electronic components, used to protect the warfighter, are susceptible to ESD damage. Protection from such damage is largely attributable to possessing an understanding of the product susceptibility thresholds, and putting robust, cost effective solutions in place to be competitive in today's market.

Case-study test results indicated a Charged-Device Model event risk where robust Human Body Model protection processes were in place. A review of this study will include discussion of some of the newer ESD event detection equipment and techniques used to determine areas in need of attention. Proper use of this equipment aids in characterizing material properties such as surface resistance and tribocharging. Understanding the risks and correcting issues cost effectively in a class Ø facility are discussed in detail.

Implementation of safeguards and employee education increases yields and decreases system returns by eliminating latent defects. Examples will be reviewed, and data provided, which support the paradigm that an in depth understanding of product design, material selection and work environment are key contributors to robust ESD protection.

Key words: ESD protection, Class Ø, Charged-Device Model, Tribocharging

Introduction

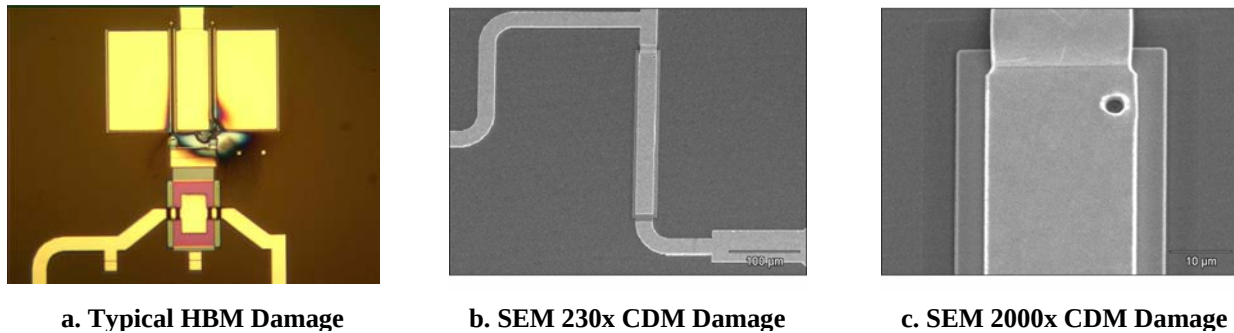
In today's extremely competitive defense market there is considerable pressure to minimize production costs to meet customer requirements. We will take a look at a case where a mature product line began to exhibit signs of a recurrent failure mode. The root cause and failure mode, identified as a catastrophic CDM ESD event, will be discussed. The process by which the technical information was gathered, the technology learned during this journey, the tools used to collect data, and the cost effective measures that were implemented to protect the sensitive devices will be discussed in detail.

Background

The ESDA's technology roadmap¹ published in March of 2005 indicated that by the year 2010 ESD sensitivity boundaries for a majority of RF devices would be at ~100V HBM and ~50V CDM susceptibility levels. This could not have been clearer when we found an increase of failures over the course of a year from an average of 3 per month to 11 per month and had a system return which was attributed to CDM ESD damage. The system return unit was troubleshoot and SEM analysis of the failed PHEMT (Pseudo-morphic High Electron Mobility Transistor) device clearly revealed CDM damage to

an output blocking capacitor (See Figure 1b & 1c). This is partially attributable to design considerations where higher frequency requirements often make it impossible to add protection circuitry due to their frequency robbing characteristics and large "real estate" requirements. Additionally, PHEMT designs have lower breakdown voltages due to thin dielectric layers. These design trade-offs for performance mean that damage susceptibility voltage levels are lowered.

Susceptibility testing indicated that the damage threshold of the component was ~200V HBM and ~275V CDM. Historically the failure rate of the PHEMT chip had increased over time and at the time of positive root cause identification had a failure rate of 0.12%. When calculated, with various costs associated with returns from different levels of assembly, the estimated annual cost of ESD damage attributed to this failure mode was placed at \$1,500,000.00. With that data in hand and an understanding that additional safe handling precautions were necessary, a consultant² was hired to assess our facilities and help guide us in understanding our strengths and weaknesses in our current ESD program to cost effectively put solutions in place that would prepare us for working safely with components having low voltage susceptibility levels.

**Figure 1**

Characterization / Classification

Figure 1a shows an induced example of a HBM model ESD event failure. Figures 1b & 1c are actual SEM images of our failed device. Note that in Figure 1b the damage is not readily noticeable even at 230x. This is one reason why it is sometimes very difficult to pin point CDM ESD damaged as it is often very small and unnoticeable to the human eye at standard 30x inspections, whereas damage caused by HBM ESD events are often noticeable. Once the failure was classified as CDM and, most importantly, the threshold limit was identified we knew a factory capable of being safe to a 100V level was necessary, thus providing a 2x margin of safety. It is important to note that by no means are all the implementations we are to discuss going to safeguard our factory for all class Ø devices. Rather, we are safe to 2x the lowest device sensitivity that we manufacturer.

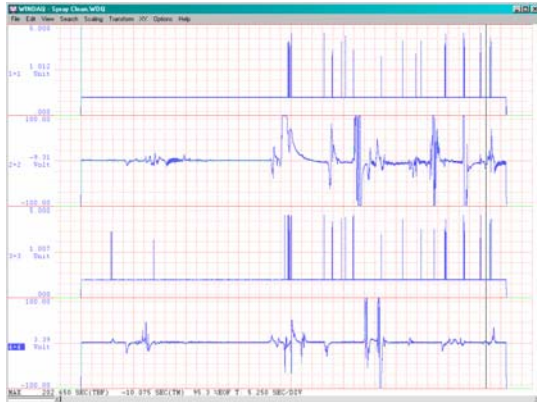
Implementation

Realization of the need for a class Ø ESD program came at just the right time as we were in the final planning stages of a factory reconstruction. Our first crucial decision was to choose proper flooring. We selected a low-charging static dissipative floor which would meet the requirements of ESD S20.20, ESD STM97.1 & 97.2. Additionally, we chose to implement an ESD shoe policy instead of heel straps. Several factors played a part in the decision. First, personnel would not have to be trained to put ESD shoes on. Secondly, a return on investment indicated a 25 month payback and performance documented as much better than just heel or toe straps. The decision to go with flooring and a shoe policy was not easy or inexpensive. However, we determined that if we did not make this significant investment our future cost competitiveness would suffer.

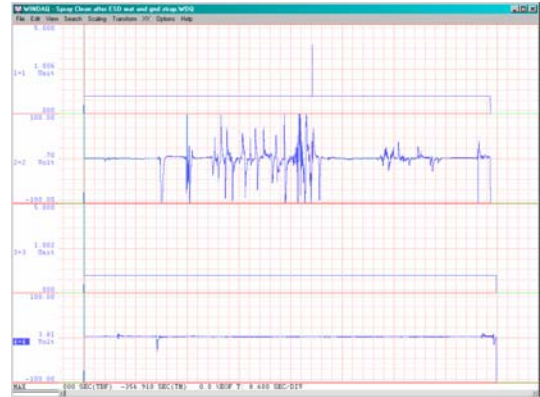
Since our HBM safeguards were in good order our next step was to assess the rest of our program and see where focused attention was required to identify and correct the CDM issues. An ESD assessment kit was purchased and a small team of individuals were trained on the usage of the components within the kit while others were tasked with a total review of ESD program documentation. This was a critical step in our success as some very old Mil-Specs were referenced and some were even obsoleted. A decision was made to develop a document based on ANSI/ESD S20.20 compliance, however, no standard including S20.20 provided for class Ø protection. Therefore our internal documents had to be modified, with justification, to include class Ø safeguards. This effort from root cause identification to class Ø level protection to 100V took approximately a year. Various testing instruments from the ESD protection kit were used for a variety of tests, tasks, and studies, several of which will be discussed in more depth later. The instruments include, but are not limited to, field meter, static decay timer, circuit analyzer and a resistance measurement system. Additionally we used event detection devices to assess various areas where sensitive components are handled.

Event Detection

An initial sweep of the factory with event detection devices indicated areas of concern that warranted further investigation, root cause and the appropriate corrective action. In one case a cleaning station was identified as an area where events were being detected. Upon closer evaluation of the station it was noticed that multiple areas, of metal to metal contact, were present which increases the risk of



**a. Cleaning station events recorded initially
>500V CDM model**



**b. After implementation of safeguards there
were no events. 1 event was induced to
indicate functional event detector**

Figure 2

damaging ESD events. Event detectors were placed in close proximity while multiple operators were watched to determine the exact root cause of the events. Figure 2a, lines 1 & 3 clearly show 13 periods of events measured at over 500V CDM. Lines 2 & 4 indicate static seen in the area during processing. After a complete review of the process and associated recorded events the appropriate steps were taken to ensure ESD event elimination. Process modification was necessary to bring cleaning fixtures and product to the same potential. Dissipative mats were installed in the cleaning system and new operator wrist strap ground points were installed that tied directly to common point AC ground. Having common grounds was instrumental in us succeeding in our efforts to protect our product to the necessary levels. Additionally metal to metal contact was avoided wherever possible. After implementing numerous changes the process was once again evaluated by means of event detection. Figure 2b shows that no events were experienced after the safeguards were put in place. One event noted on the chart was purposely induced after the testing was completed to indicate that the detector was functioning properly. By spending approximately \$100.00 in materials and a few hours of labor this cleaning station was now safe to the level of protection required. This similar type of work had to be repeated across the whole factory and at every workstation in order to be 100% effective.

Double Jeopardy

In addition to testing workstations all automated equipment had to be monitored for ESD events. One of the items to be aware of in automation is a phenomenon referred to as “double jeopardy”. In one case we changed our insulative tooling to a static dissipative tooling platform to protect against this type of ESD occurrence. Figure 3 shows an example of how a metal device can be subjected to two ESD events by means of coming in contact with a charged insulative material or fixturing. As a device moves into automated equipment it can be inductively charged by a charged insulative material (Fig. 3a). As the unit undergoes some processing and is subjected to grounded tooling the unit is discharged to ground thus experiencing and ESD event (Fig. 3b). As the device is transported out of the equipment and away from the charged insulative material the device now has an equal but opposite charge (Fig. 3c). This occurs because the insulative material cannot give up its charge by means of grounding. If the device is once again contacted to a ground source it will experience another ESD discharge event (Fig. 3d).

The waveform can be clearly seen in Figure 4. By changing to a static dissipative tooling platform the devices were not subjected to charging via induction and thus the risk was eliminated.

In cases where elimination of an insulative material is not possible, engineers may consider using ionization to eliminate charge from the insulative material.

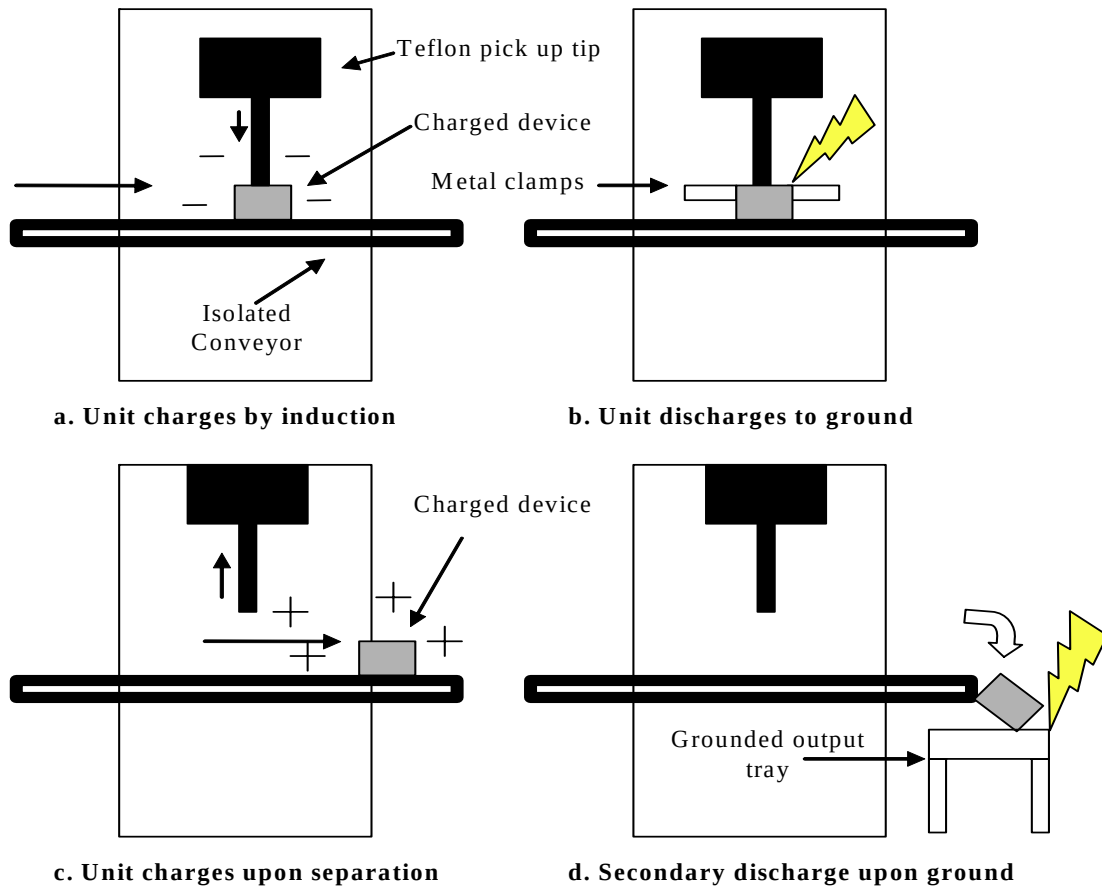


Figure 3

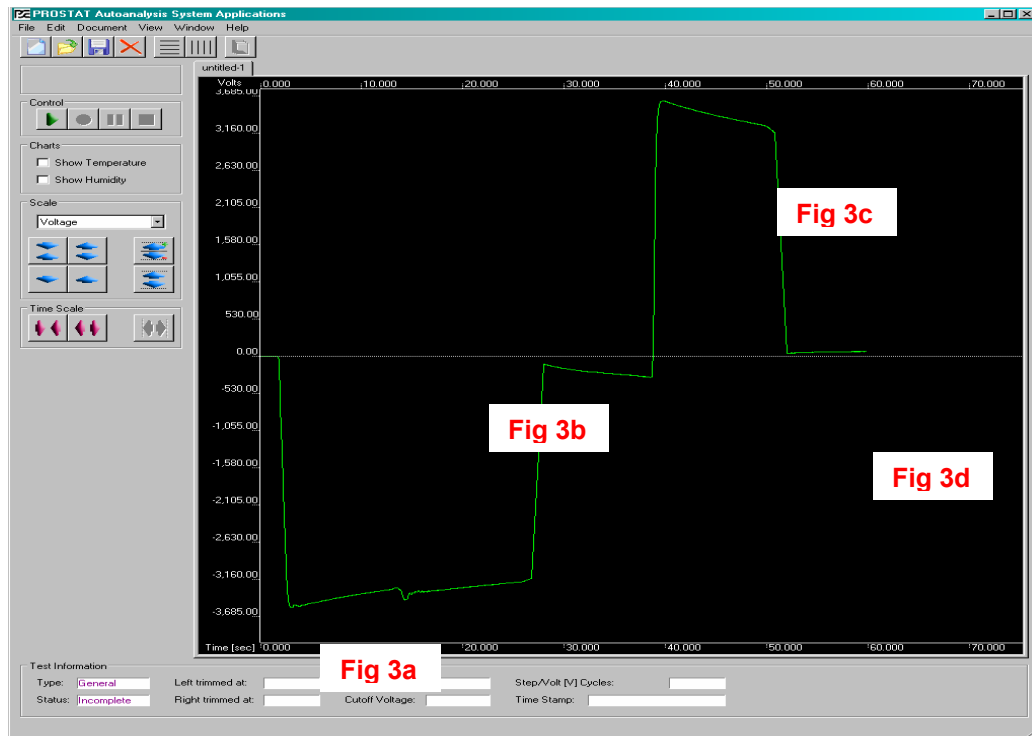


Figure 4

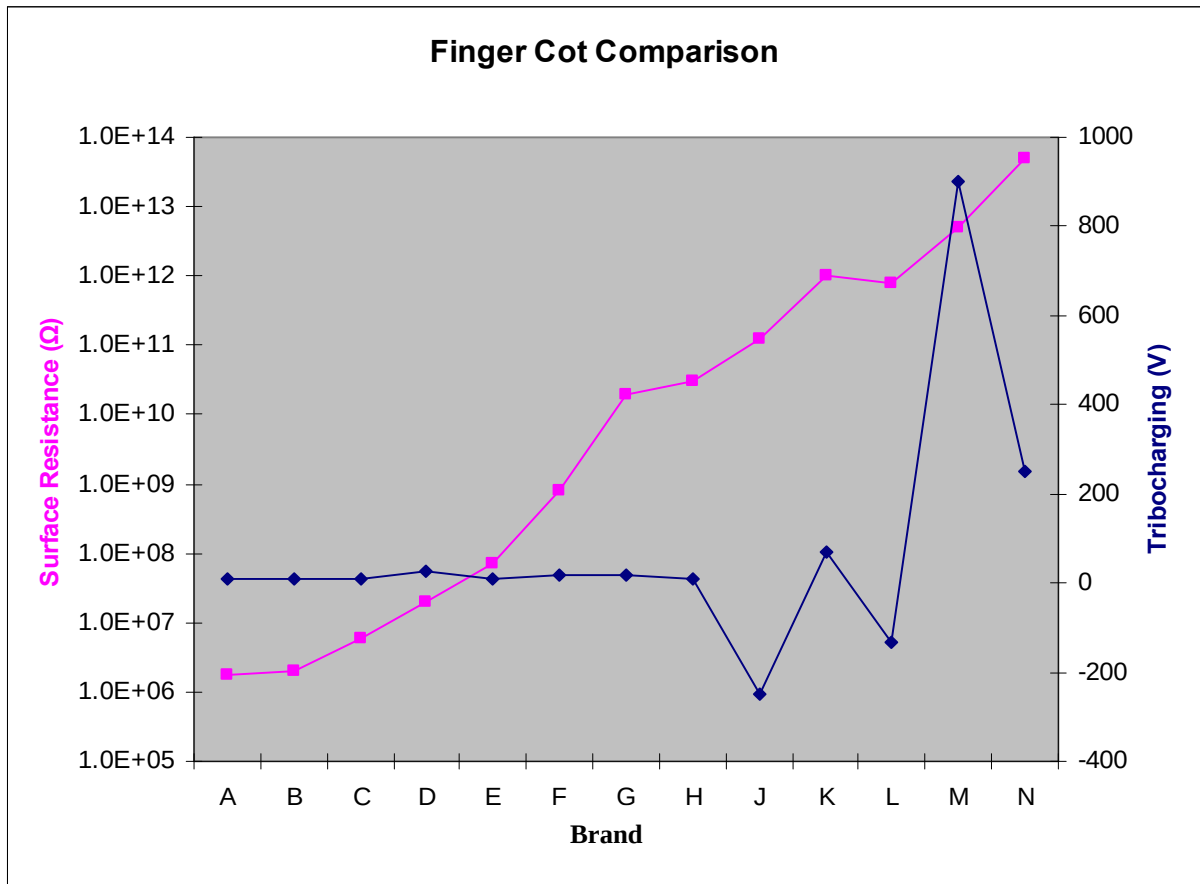


Figure 5

Finger Cot Study

An important area to study is finger cots as they often come into contact with ESDS devices. These are commonly used throughout the microelectronics industry mainly to prevent oils from one's skin from contaminating the product. Depending on the surface resistance and level of tribocharging on the cots, ESDS devices can be at risk.

Thirteen brands of finger cots, 9 latex and 4 nitrile were tested. Cots from each brand were measured for surface resistance by unrolling cot on an insulated surface and using a small concentric ring electrode probe with a wide range resistance meter. Tribocharging was measured by unrolling a finger cot and hanging it from a non charging insulated wire. The cot was gently rubbed with same brand grounded finger cotted forefinger and thumb and then the hanging cot was immediately tested with an

electrostatic voltage meter from distance of 1 inch. To determine if ESD events could be caused using particular cots a metal device was handled while grounded with each brand of cots and dropped onto a large metal surface with an event detector placed 6 inches away and set to pick up damaging events.

As shown in Figure 5, surface resistances ranged from 1.8E6 to 5.0E13 ohms with the nitrile cots ranging from 2.0E10 to 1.2E11 ohms. Cot to cot tribocharging was close to neutral for all cots <E10 ohm range, but was as high as 900 volts for Brand M pink latex cots. Three of the 13 cots (L, M, N) induced charge on a metal device and thus led to a CDM event. It was noted that the nitrile cots had poor dexterity and thus would not be comfortable to wear while handling product.

There is a strong correlation between high surface resistance, tribocharging, and generation of ESD events. When choosing a finger cot to implement at a facility with ESDS devices, one must at a minimum test for surface resistance to verify they

are dissipative, preferably in the E6 to E7 ohm range. A cot in this range will ensure good grounding through the cot to a grounded human body. Testing for tribocharging of the cots and ESD events is also recommended to ensure protection. There are several cots in the industry (A through E) that will meet class zero ESD needs and a couple of those brands are at low cost, but there are many brands that should not be used in class zero facilities.

Packaging

Packaging requirements was another topic of significant importance that was studied. At the time of our initial factory assessment, metallized bags, metal trays, and conductive cardboard boxes were in use. We quickly learned about various problems associated with those materials.

It is well known that metallized bags with thin dissipative coatings can protect product from DC fields and static discharge. This thin dissipative coating is not permanent and when bags wrinkle the coating is compromised. We determined that our products are not susceptible to DC fields and thus a metallized bag is not required. What is required is a permanently dissipative non-tribocharging bag that will meet the requirements of MIL-PRF-81705D Type II. We actually found that bags such as these were already being used in areas throughout the company and now are the main choice of bags due to their permanent dissipative properties allowing unlimited use.

Many of our products were transported throughout the factory in conductive corrugated plastic boxes with conductive foam both measuring in the conductive E2 ohms scale. Since this material is not static dissipative it presented a potential CDM event risk, so we switched over to static dissipative carbon impregnated corrugated cardboard boxes with a static dissipative foam or a thermoformed static dissipative plastic insert with good resistance to heat. Many processes on the factory floor require product to be processed and transported in trays. Nearly all of our metal trays were replaced with static dissipative fiberglass composite trays that can withstand high process temps.

Finding a waffle pack manufacturer that will spec a material completely in the middle to low end of dissipative range has been a challenge. Often the specified resistance range is conductive and dissipative for one material. We have recommended to material experts in the waffle pack arena the growing need for a black static dissipative waffle

pack. The overall sentiment is that it is difficult and costly for manufacturers to consistently hit the narrow 1 to 2% window of carbon concentration by weight that is required for dissipative surface resistances. This is why specifications straddle both the conductive and low dissipative range.

Conclusion

Understanding the susceptibility level of your most sensitive device is paramount in cost effectively preparing your factory for Class 0 protection. In our case, protection was set at two times the most sensitive device level. Thus our 100V limit provided a margin of safety double the most sensitive device (200V threshold) susceptibility level. Protecting to any lower level would have been poor use of resources as it would have had neither added value nor reduced risk in any way.

A comprehensive systems approach was employed to address the many different facets of ESD control. The dormant ESD committee was re-energized with representation from all areas and functions. Production operators were trained as Process Checkers to perform daily visual inspections on their work areas. Discrepancies were logged in an on-line database and corrective actions were verified when completed. An auditor was hired and trained to perform bi-monthly audits on all of our factories. These audits utilized a statistical process control approach where sample data was collected from each area on bench mats, chairs, floors, wrist straps and other ESD items.

A concerted effort by our ESD team was done in partnership with upper management support to fund the diverse activities. The necessary measurement equipment was purchased to empower the ESD team with the needed tools to characterize ESD materials and events. The event detectors were totally new to our ESD team and provided data that did not exist previously. The event detectors were superb at finding areas which needed further investigation and corrective action. One challenge was sorting out the background noise from the actual product related events. Static field and resistance meters were excellent at characterizing material properties to determine if they were suitable for the ESD applications. Finding dissipative materials with low tribocharging properties was usually possible but took some investigative work! Avoiding all metal to metal contact was more difficult because of equipment and fixture design but some solutions have been found in this area also.

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