

Direct discharges from ESD fabrics

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Abstract

There are three main ways that the system, operator- protective garment, can affect a sensitive device, namely: direct electrostatic discharges (ESD), ESD due to induced charges, and induced current and voltage transients due to electro-magnetic radiation. The purpose of this paper is to describe direct discharges from a Protective Fabric (PF) to a sensitive device. One way of estimating this is to measure the amount of charge available in a discharge from a PF. A PF has the ability, at least partly, to discharge itself when grounded and to average out surface charges when not grounded. This is usually achieved by adding a conducting mesh (carbon or steel) to an ordinary fabric (cotton, polyester and/or nylon). A number of available PF's are tested and discharges from these fabrics are measured with two different ESD probes. The charging methods used in this study are tribo-electrification and direct contact. We conclude that discharges from the conducting mesh on the fabric is measurable, even for small charge densities, because of its ability to redistribute the charge when affected by the ground potential of our ESD probe.

Introduction

The consumers demand for smaller, faster and cheaper electronic products is forcing the manufacturing industry to push all limits further. This of course makes some of the new components more sensitive to damage by Electro Static Discharge (ESD) than previously, also the use of new technology and new materials changes the scenery and demands on the general ESD awareness. One can speculate about future demands on production sites for having potentials lower than 50V inside the manufacturing area (a common value today is 100V). A change with a factor of two (indicated above) would probably force the entire ESD community to re-evaluate many of its concepts and solutions of handling the ESD protection.

The work presented in this paper is part of a European research project called ESTAT-Garment [1,2]. The purpose of this project is to evaluate all present test methods for ESD protective garments, including the test methods for fabrics, for present and future demands. One possible output from this project is a new test method for the whole system: Operator - Protective Garment - Sensitive Device. The output from this project will be taken into account when the IEC technical committee for electrostatics develop a new proposed standard for ESD protective garments.

Protective Garments (PG's) are today widely used in the electronic manufacturing industry. The purpose with these special garments is to protect sensitive devices during the manufacturing process from ESD generated by the operator. An operator inside a manufacturing area in the electronic industry should normally be grounded by a wrist strap or by special conducting ESD-shoes, however this grounding affects only the conducting parts of the operator. The normal garments worn by the operator are not always guaranteed to be conducting at all normal working conditions in the production site and this is the reason the operator wears the PG over his normal clothes. The PG should be grounded or electrically connected to the operator's body, but in many

real factories we have observed that this grounding is not achieved. In this case the PG is free to acquire a voltage and become itself the source of ESD.

In this study we focus on direct discharges from fabrics, especially on discharges from protective fabrics (PF's), that is, fabrics that are used for manufacturing protective garments. A PF can, in some sense, be characterised by its ability to redistribute charges on a time scale that is essentially shorter than the redistribution time scale for an insulator. This is usually achieved by adding a conducting mesh of carbon or steel, to an ordinary and normally insulating fabric made of cotton, polyester and/or nylon. There are a number of different protective fabrics available on the market and within our project we have chosen a selection of them.

One way of evaluating ESD risk is to measure the peak ESD current in a direct electrostatic discharge, see reference [2]. To measure the discharge current from the fabrics we have used two different discharge probes. The probes and fabrics as well as the discharge events will be described in the following paragraphs.

Probes and experimental set-up

We have used two different probes to detect the discharge currents from a number of different discharge events. The basic design for both these probes is the same. They are both passive probes that divert a given ratio of the current into the 50Ω impedance input of an oscilloscope. The probe designed at SP (Sweden) will be referred to as (SP-probe) in the text and the probe bought from Jeremy Smallwood will be referred to as (JS-probe) in the text, for details about the JS-probe see reference [3,4,5]. The total current of the discharge event can easily be calculated by multiplying the values recorded by the oscilloscope with a probe specific scaling factor. In our case we have factor of 10 for the SP-probe and a factor of 2 for the JS-probe. In figure 1 we illustrate the principle of both the SP-probe and the JS-probe and their connection to the oscilloscope.

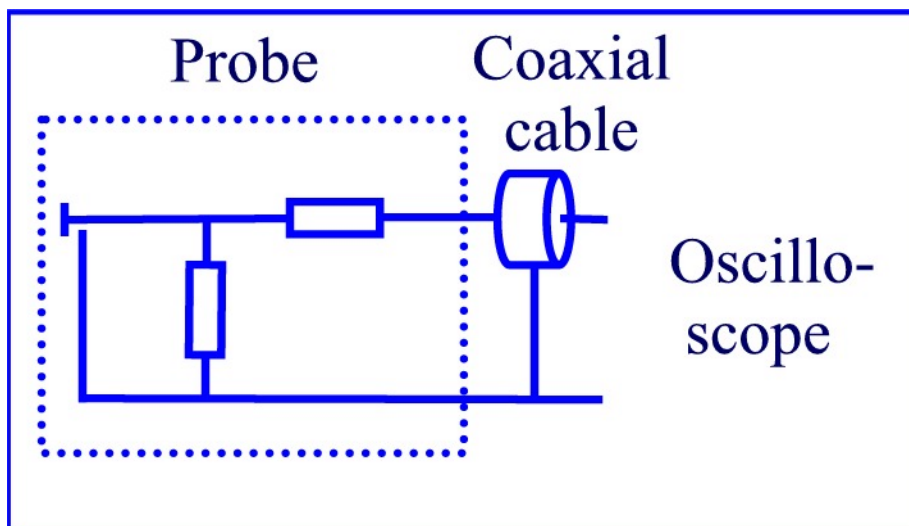


Figure 1 shows the principle of the probe and its connection to the oscilloscope.

The resistors in figure 1 are, in both probes, encapsulated in a metal container that is connected to ground potential. The vertical bar in the left part of figure 1 indicates the discharge tip of the probes. In the case of the JS-probe it sticks out around 2mm from a grounded 20 mm hemispherical shield, and in the case of the SP-probe around 15mm. The oscilloscope had, in our measurements, a bandwidth of 300MHz and a sampling rate of 2,5Gs/s. The connecting cable was a normal 50Ω coaxial cable. In figure 2 we see the JS- probe and in figure 3 we see a picture of the SP-probe.



Figure 2 shows the JS-probe.

In figure 2 we can see the JS- probe. The tip is barely visible, but it is sticking out from the left side of the half sphere.

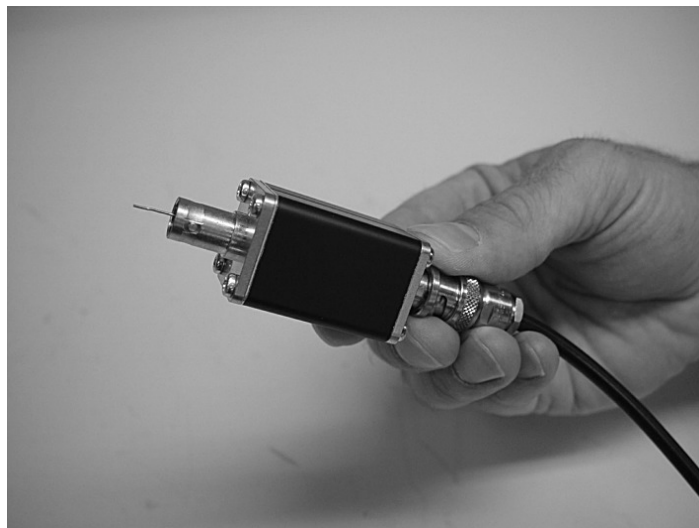


Figure 3 shows the SP-probe.

In figure 3 we can see the SP-probe with its needle like probe tip on the left side of the picture. We have compared needle like tips with tips having a rounded form and found the peak current to be slightly, but measurably, higher for the needle shaped probe tips.

A principle picture of the experimental set up is presented in figure 4. On the right hand side of the figure we have the oscilloscope, the coaxial cable and the probe. This subsystem of the measurements system has well defined signal paths and well defined limiting data. On the left hand side of the figure is our test object and a ground plane.

The measurements were made in the following way: We fastened the protective fabrics, of the size around 24cm x 24cm, in a conducting frame of the same size. The frame with the PF was then placed about 5cm from a large ground plane, see left part of figure 4, with a field meter mounted in the centre (not indicated in figure 4) of this ground plane. This field meter was used to measure the average potential of the system, consisting of the test fabric and the frame. The output potential from this field meter was used to estimate the amount of charge put on the fabric and the frame.

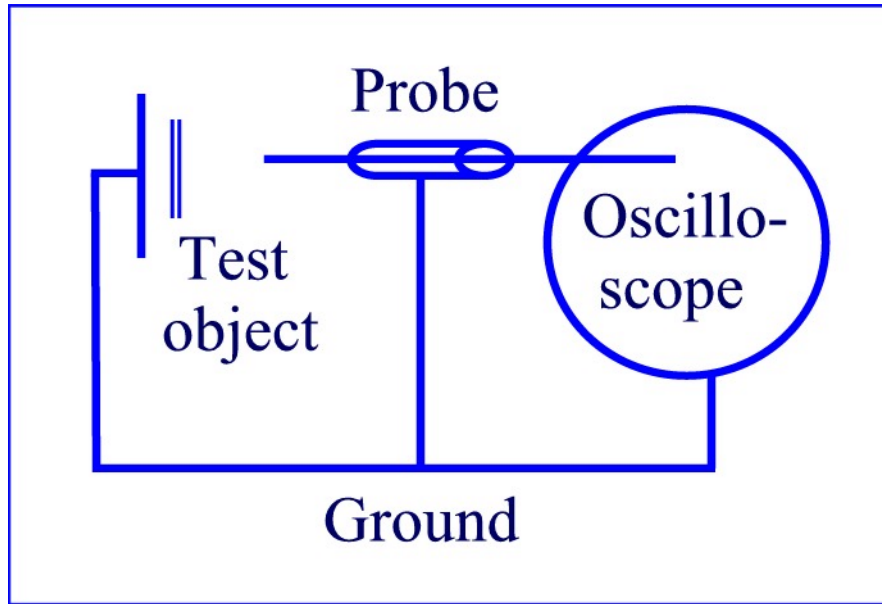


Figure 4 shows a principle picture of the experimental set up.

Fabrics

The main purpose of a protective garment is to shield sensitive devices in the production phase from static electricity generated in the normal clothing worn by the operator. The major difference between a garment and a fabric is the seams. We do not intend to discuss different seams and their various constructions only differences between fabrics in this paper. In this study we have included mainly protective fabrics with three different kinds of conducting threads namely: Core-conducting carbon fibre (CC), Surface-conducting carbon fibre (SC) and Stainless steel fibre (SS). The conducting threads are woven into the main fabric in a square lattice. We have access to two different lattice sizes, namely: 10mm x 10mm and 5mm x 5mm. Polyester or a cotton-polyester mix makes up the main part of these fabrics. We will label our different fabrics CC10, SC10, SS10, CC05, SC05 and SS05, where the “10” in SS10 stands for the 10mm x 10mm and SS according to the definitions above. In these tests we have not observed any difference between the different main materials, as in the differences between cotton and polyester. Such differences exist, but are not visible in our measurements. All our test fabrics are preconditioned in 23 degrees Celsius and 12% RH for at least 72 hours before the measurements. The measurements are also preformed under these conditions.

Discharges and charging

To make a discharge from a test fabric we must firstly charge it. In this investigation we have used tribo-electrification and direct charging of the test object. Tribo-electrification means that the test object is rubbed with another object until there is some charge difference between the objects. In our cases we rubbed a Teflon disc, of diameter 5cm, against our test fabric until the average potential reached a given value (typical 1000V). This procedure would take at least one minute to complete and then the test fabric would be left for another minute to rest before it was discharged with one of the test probes.

The other charging method with direct charging can only be used on conducting material or on conducting parts of the fabrics. Here, we apply a given voltage to the frame with the protective fabric and then wait around two minutes before the fabric is disconnected from the voltage, and then the fabric is discharged through one of our two discharge probes.

We will firstly compare the probes with each other, secondly we will compare the discharges from different charging mechanisms with each other and thirdly we will compare the different protective fabrics with each other. In general, one can say that single peak discharge events are not very common using hand held probes, usually we record a large number of peaks however in this report we chose to present only one of those discharge peaks.

To compare the JS-probe with the SP-probe we made twelve different discharges from the stainless steel fabric SS10. The fabric was directly charged with 200V during two minutes. The discharge was taken directly from one of the conducting threads in the centre of the fabric, with the probe being held by hand during the whole process. The average charge contained in a discharge was 5,0nC for the SP-probe and 6,5nC for the JS-probe. The current, as function of time for a typical discharge event, is presented in figure 5. The thin line corresponds to the SP-probe and the thick line corresponds to the JS-probe.

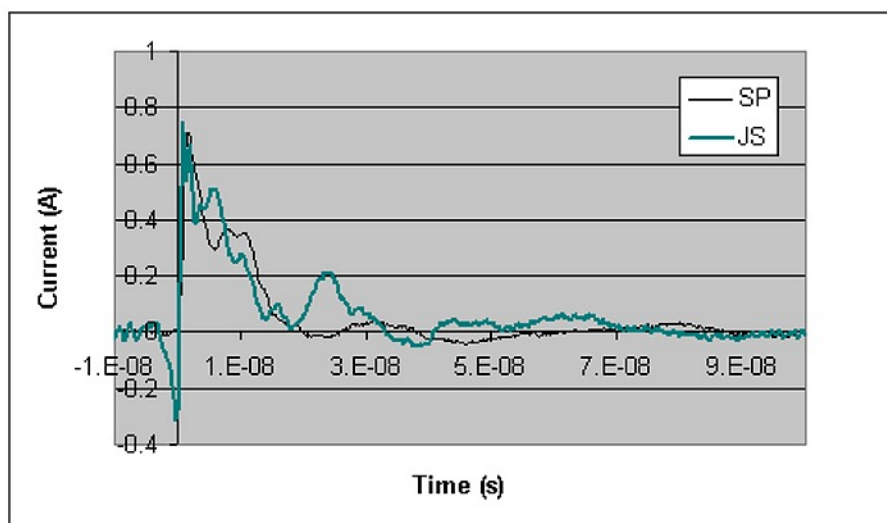


Figure 5 shows a typical discharge current from a SS10 fabric charged to 200V.

It is interesting to note that the amplitudes and the shape of the discharge currents are very similar between the two different probes, as shown in figure 5. The average peak current was 0,66A for the SP-probe and 0,69A for the JS-probe. This peak current corresponds to the likely threshold of damage to a 1000 V HBM (Human Body Model) withstand electronic device.

Comparing discharges from tribo-electronically charged fabric with discharges from a directly charged fabric is very difficult for the insulating parts of a fabric, since one can not charge the insulating parts of the fabric directly. There is one factor however that makes this possible. The size of the conducting mesh is small. If the grid had been larger, then the relaxation time after the tribo-electric charging of the fabric wouldn't have been sufficient, as we would have had more charge in the insulating regions of the protective fabric. It was not possible to get a direct discharge from these regions with the amount of charging that we used in these tests (we made several attempts). However, one can discharge the fabrics by grounding the insulating part of the fabric, but not use our probes to detect the currents, these currents are too small. In figure 6 we show examples of two different discharges which both are registered with the SP-probe, direct charging is indicated with a thick line and tribo-electrical charging is indicated with a thin line. The fabric used in this experiment was the core-conducting CC05.

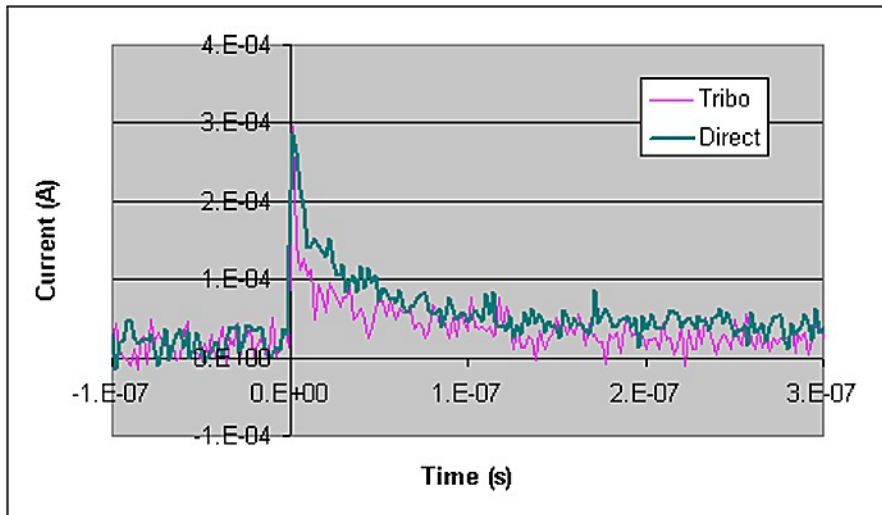


Figure 6 shows discharges from different charging methods for the CC05 fabric.

The two discharges shown in figure 6 are similar both in amplitude and in shape. The offset seen in figure 6 is compensated for, in the presented values. Five different discharges were made for each charging case with the average and charging potential fixed at 1000V. The average peak current was 0,33mA for the direct charging and 0,27mA for the tribo-electric charging of the core conducting CC05 fabric. The average charge recorded during these discharges was 36pC from the direct charging and 31pC from the tribo-electric charging. As a rough estimate one can say that direct charging and tribo-electric charging gives the same discharge currents and charges, under the assumption that we follow our given measurement prescription. Similar tests were also made for the fabric with surface conducting carbon fibre and for the fabric with stainless steel fibres. These tests indicated that this charging approximation also holds for the other fabrics.

To compare the different fabrics with each other we need to make a large number of measurements. Average charges and average peak currents are calculated from around six different discharge events. The charging method used in this part of the report is the direct charging method described earlier. The discharge probe used for these discharges is the SP-probe.

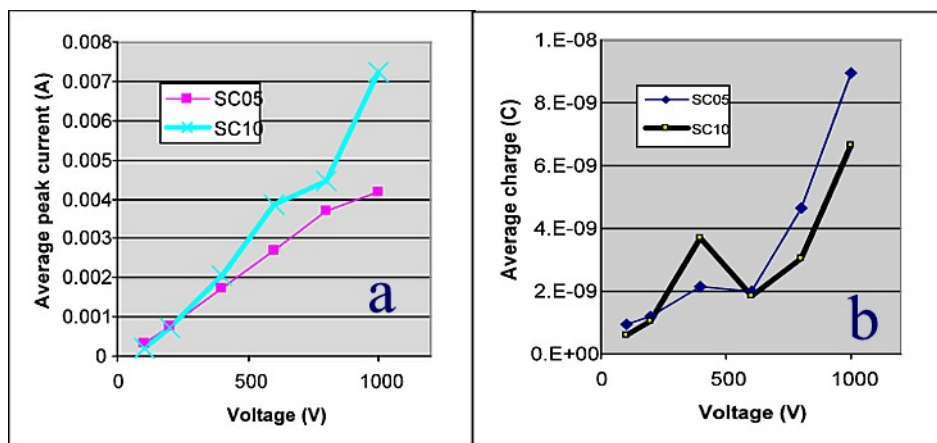


Figure 7 a shows the average peak discharge current as function of charging voltage and figure 7 b shows the average charge from a discharge as function of the charging voltage for the SC05 and SC10 fabrics.

In figure 7a we see the average peak discharge current, recorded with the SP-probe as function of the charging voltage and in figure 7b the average charge is plotted as function of the charging voltage for the fabrics SC05 and SC10. The thin line corresponds to the SC05 and the thick line to the SC10 fabric in both figure 7a and figure 7b. One cannot say that there is a clear difference

between the two different grid sizes from the plotted values, but the scaling relation between the average charge amount / average peak current and the charging voltage is clear.

For the core conducting carbon fibre CC05 and CC10 we have done the same, namely, using the direct charging method and the SP-probe for registering the discharges with. In figure 8a we show the average peak current as function of the charging voltage.

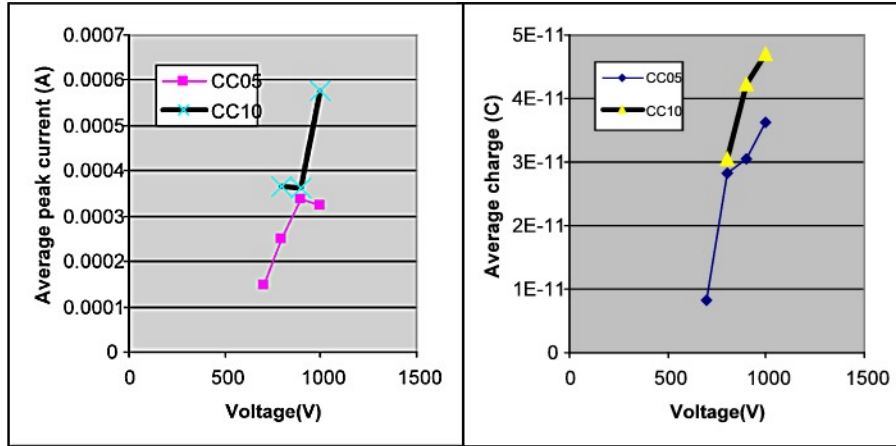


Figure 8 a shows the average peak current as function of the charging potential and figure 8 b shows the average charge from a discharge event also as function of the charging potential.

In figure 8b we see the average charge from a discharge event as function of the charging potential. The thin lines correspond to the CC05 fabric and the thick lines to the CC10 fabric. It is not clear for this fabric that one can see any significant difference between the different grid sizes. The scaling relation between the charging potential and the measured entities is less clear than it was for the SC05 and SC10 fabrics. Below the charging potential of 700V no discharge events were registered. The reason for this is unclear, either it could be that the oscilloscope couldn't register the discharges or that there was no discharge below 700V. As the conductive fibres have a buried conductive core, this may be indicative of a threshold voltage required before charge can be transferred to, or from the core.

For the stainless steel fabric we only did the measurements for the 10mm x 10mm grid, this fabric was called SS10. In figure 9a we show the average peak current as function of the charging potential and in figure 9b we can see average charge as function of the charging potential. Even for this kind of conducting fibres the scaling between the measured entities and the charging potential seems to work.

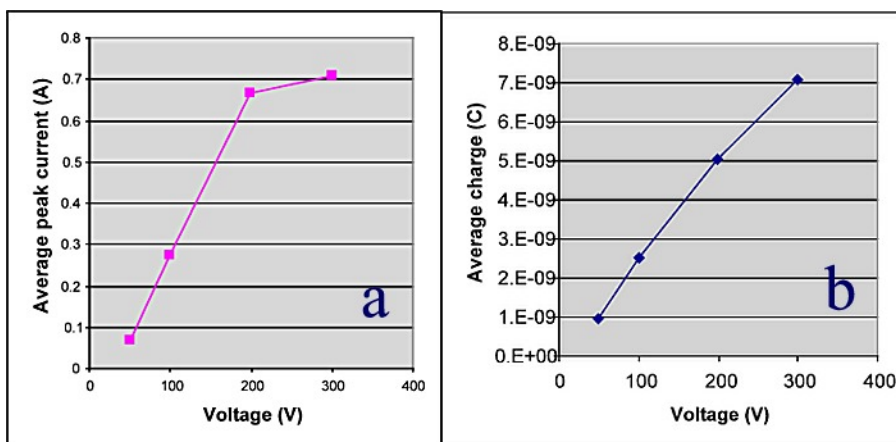


Figure 9 a shows the average peak current as function of the charging potential and figure 9 b shows the average charge in a discharge event as function of the charging potential.

When we look at the different fabrics CC05, CC10, SC05, SC10 and SS10 one can clearly see that the peak current and the amount of charge in a discharge event scale with the charging potential for all of the fabrics. We can also compare the amount of charge and the peak current between the different fabrics. This would, for a given charging potential, result in the following order of the fabrics for decreasing peak current and charge: SS10, SC10 and CC10. This actually also corresponds to the ranking of increasing surface resistances of these fabrics (SS10 has the lowest value). We have not yet tried to calculate the ratios between the different peak currents and the ratios between the different surface resistances. This will indeed be interesting.

References

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