

ESD-protective clothing for electronics industry – A new European research project ESTAT-Garments

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Abstract

Current standard test methods for the evaluation of the performance of modern ESD-protective clothing used in electronics industry do not measure correctly the effectiveness of the clothing to protect sensitive electronics from electrostatic phenomena. Therefore a new European research project – ESTAT-Garments – was started in early 2002. The main objective of this three-years project (2002-2005) is to supply the standards body IEC TC101 with a basis to qualify the effectiveness of clothing used for the ESD-safe handling of electrostatic discharge sensitive (ESDS) devices and to develop appropriate test methods for the characterisation of such ESD protective garments.

1. Background

The evolution of electronics has led to the development of products in which increasing number of operations concerning an increasing amount of data can be performed faster and faster per each generation of devices. The improved properties and the increased functionality have been rendered possible by the achievements in semiconductors science. The latter achievements mirrored an ongoing reduction of the semiconductors elements dimensions. Unfortunately, this evolution lead to devices which are more sensitive to electrical disturbances than ever before. One such disturbance is caused by electrostatic discharges (ESD). Most ICs can withstand ESD in kV-range but, on the other hand, many discrete components are in the range of 100 – 150 V according to the standard Human Body Model (HBM) ESD test [1]. And the number of ultrasensitive devices with ESD withstand voltages below 100 V is increasing (including magnetoresistive (MR) recording heads, special rf-devices, flat panel displays and CCD devices, etc.). Overview of device technology HBM withstand voltages (sensitivities) is given in Table 1.

Investigations performed in different parts of the world show that about 30-50 % of all failures in electronic products detected during manufacturing can be attributed to some kind

of electrical overstress, of which ESD is one type, see e.g. [2]. Electric charges present on the operators clothing are a source of ESD in the manufacturing environment. These charges are typically accumulated when the operator is moving, that is, by tribo-electric effects (rubbing or separation of two different materials). Specially designed protective clothing is used to avoid accumulation and the retention of the latter charges. This clothing, called ESD-garment, is worn over the ordinary clothing of the operator.

The present standards for the evaluation of the ESD-garments protective performance [3,4] are mainly based on the results of researches performed in the 80's. Such methods, as well as the garments, satisfied the requirements of that time. Since then the electronics industry demanded increasing performances from the ESD-protective clothing.

In some cases the ESD-garments are not used just to prevent ESD-damage to electronics but also to prevent the electronics from being damaged by dust particles (clean room clothing). At the same time there has been much progress in the textile industry. As a result the ESD-garments in use today are made of composite fabrics where a grid or stripes of conductive threads are present inside a matrix of cotton, polyester or mixtures of these materials. Furthermore, the conductive threads are more and more frequently made by composites, that is by a mixture of conductive and insulating fibres (core conductive fibres, sandwich type fibres etc.), see Fig. 1 [5]. All the latter elements lead to very heterogeneous fabrics for garments. ESD risks of modern charged fabrics were investigated in a European project "The evaluation of the electrostatic safety of personal protective clothing for use in flammable atmospheres (SMT 4962079-1998)" with reference to flammable atmospheres [5]. In electronics industry the ESD risk levels are much lower than in flammable atmospheres, so the knowledge from that project cannot be directly transferred to ESD-protective clothing used in electronics industry.

Table 1 Overview of device technology sensitivities for the Human Body Model (HBM) type of ESD and corresponding ESD sensitivity classification according to the IEC standard 61340-3-1.

Technology	Typical HBM sensitivity (V)	Approximate HBM ESD sensitivity class
MR heads, RF FETs, SAW devices	10 - 100	0
power MOSFETs, PIN diodes	100 - 300	0 - 1A
laser diodes	200 - 1500	0 - 1C
MMICs	100 - >2000	0 - 2
Flat panel displays and CCDs	50 - 150	0
LEDs	500 - 8000	1B - 3
pre-1990 MOS VLSI	400 - 1000	1A - 1B
modern VLSI	1000 - 3000	1C - 2
HC and similar families	1500 - 5000	1C - 3A
CMOS B series	2000 - 5000	1C - 3A
CMOS A series	1000 - 2500	1C-2
MOS linear	800 - 4000	1A-2
small geometry old generation bipolar	600 - 6000	1A - 3A
small geometry modern bipolar	2000 - 8000	2 - 3A
power bipolar	7000 - 25000	3A - 3B
film resistor	450 - 5000	1B - 3A

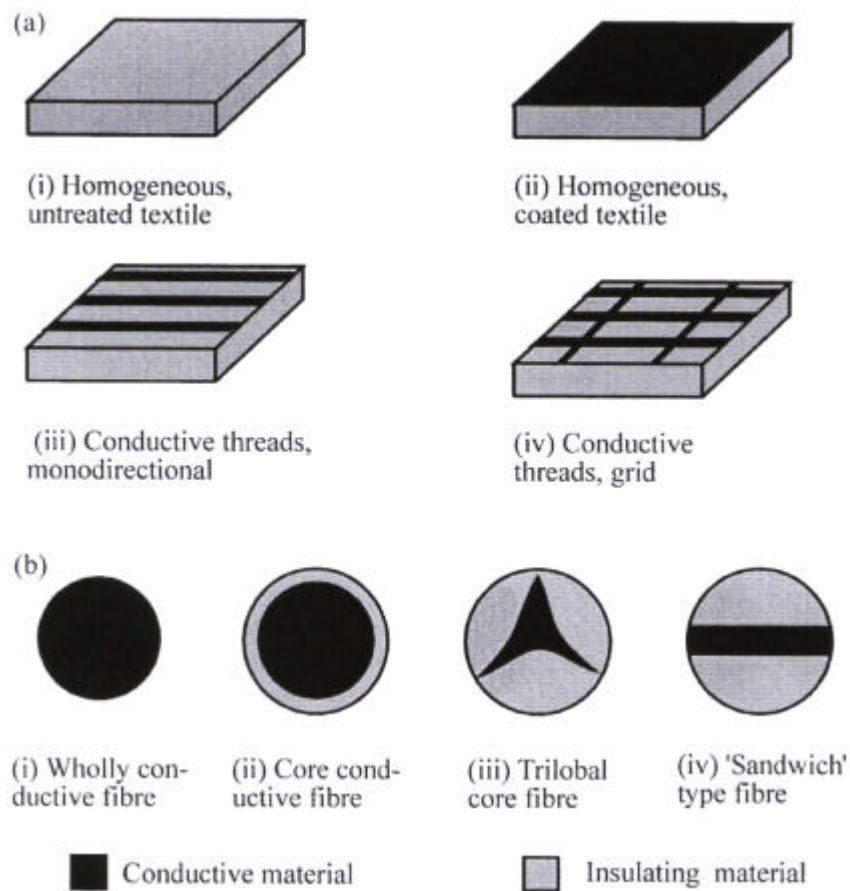


Figure 1 (a) Structures of homogeneous and heterogeneous textiles, (b) structures of commonly used conductive fibres. [5]

The presently available standard test methods for garments used in electronics industry [3,4] have been developed for homogeneous materials, thus, they do not allow a proper characterisation of the modern garments performances. Furthermore, it is not certain that they indicate how much the garments will protect the electronics from ESD. Therefore, the European Commission, in connection with the Technical Committee No 101 "Electrostatics" of the International Electrotechnical Commission (IEC), issued a call for a research about a new test method for ESD-garments.

2. ESTAT-Garments

As a response to the call, a European research project "Protective clothing for use in the manufacturing of electrostatic sensitive devices (ESTAT-Garments)" was started in early 2002. The project partners – VTT (FIN), University of Genova (I), SP (S), Centexbel (B), STFI (D), Nokia (FIN), Celestica (I) - consist of experts of electrostatics, electrostatic measurements, textile technology and electronics manufacturers (end-users of the garments). The main goal of the three-years project is to supply the standards body IEC TC101 with a basis to qualify the effectiveness of clothing used for the ESD-safe handling of ESD sensitive (ESDS) devices and to develop appropriate test methods for the characterisation of such ESD protective garments. The approach is aimed at achieving an understanding of the

electrophysical processes regarding both composite textile materials and total systems, including the ESDS devices. This means that the project includes also the following objectives:

- 1) a physical basis for understanding the electrostatic processes within composite materials at large,
- 2) an understanding of the complete system (operator, ordinary clothing, ESD-garments, ESD sensitive electronics),
- 3) results of interest for manufacturers of garments and yarns in order to give them an incentive for product improvements.

3. Risks of damage to electronics with reference to garments

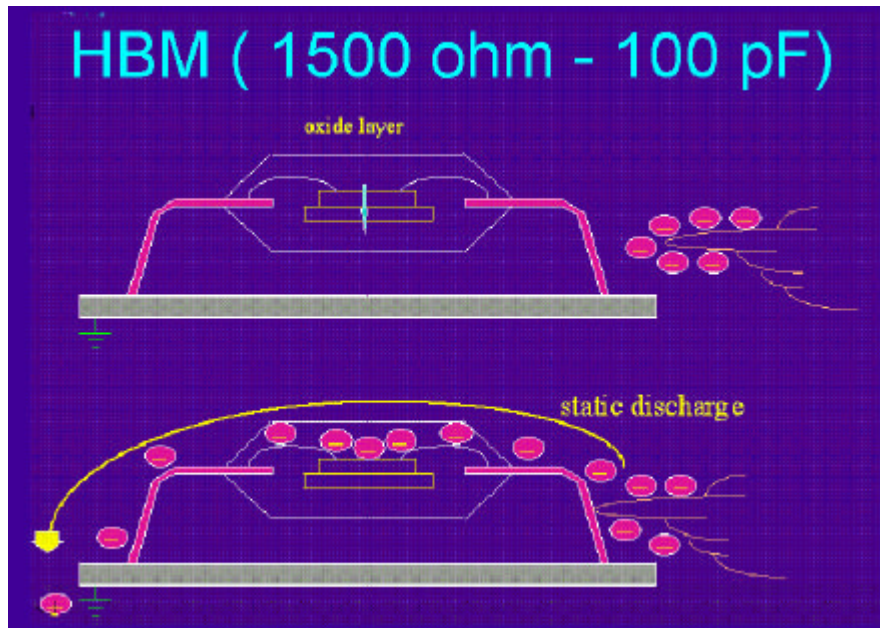
The main function of ESD-protective clothing (ESD-garments) is to protect sensitive electronics from ESD damage caused by a charged person (operator). But in addition to the charged operator, also improperly designed or improperly working, charged ESD-garment itself can be a potential source of ESD failures to ESDS devices. In the ESTAT-Garments project we have specified possible risks of damage to ESDS devices with reference to garments. In the studies the risks will be then either justified or excluded. An ESD failure caused by charged operator or charged clothing can happen, at least, in three different ways:

- 1) by a direct discharge from the body of the operator, from unearthed conducting threads of the garment, or from insulating surfaces of the garment fabric;
- 2) by discharge from the charged device. A device becomes, at first, charged by induction due to electric field from charged clothing or by triboelectrification and, after that, gets ground contact giving rise to electrostatic discharge (charged device model (CDM) type of ESD);
- 3) by radiation, a discharge from operator's ordinary clothing to his grounded ESD-garment might cause electromagnetic pulse strong enough to damage ESDS devices (indirect discharge).

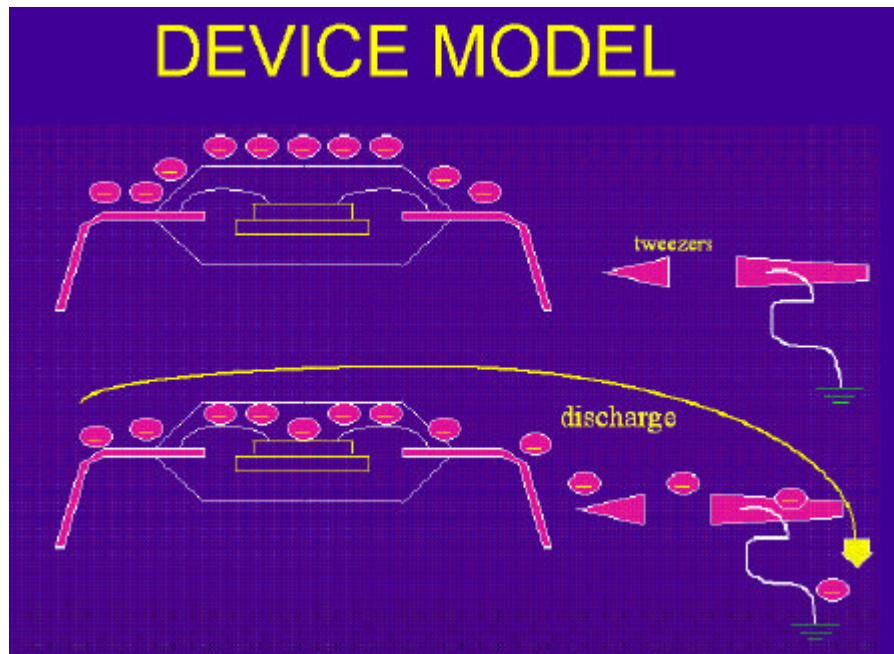
Cases 1) and 2) are illustrated in Fig. 2.

Sensitivity of electronic components to ESD is given in standards [3] by withstand voltages, which is the maximum ESD voltage a component can experience without failure. For many components, however, the true ESD sensitivity may be better represented by the discharge energy, the peak of discharge current or the peak power of the ESD, which depend not only on the ESD voltage but also on the source of the discharge as well as the impedance of the discharge circuit. A 500 V discharge from insulating fabric may cause smaller peak current than a 500 V discharge from improperly earthed conducting threads. Accordingly, an ESD from an insulator may be less harmful to ESDS electronics than corresponding ESD (in volts) from a conductor. Often also the risetime of the discharge has an important role in ESD susceptibility of ESDS devices.

If assessing the risk of ESD with reference to garments, we should take into account the risk from electrostatic fields, the risk from direct discharges, and the risk from indirect discharges. Electrostatic field external to the garment gives rise to risks of induced charge on a device, that could lead to CDM ESD damage. The strength of the electrostatic field depends on 1) rate of charging of the garment material, 2) rate of charge dissipation of the garment materials, 3) ability of the garment material to shield the electrostatic field of underlying garments, and 4) suppression of fields by coupling to the body of the person wearing the garment. Direct discharges from conducting elements or insulating parts of garment may cause damage by charge injection to the device. The exact discharge waveform will depend



(a)



(b)

Figure 2 Illustrations of a direct discharge from the body of the operator to a device (a) and a discharge from a charged device to ground (b).

on the electrical characteristics of the ESD source and victim device. Direct discharges are probably the most important source of ESD failures caused by improperly working ESD garments. Risks from indirect discharges are related to EMI currents induced by nearby ESD. Induced EMI currents can damage ultrasensitive components, but a strong ESD source would be required. In an ideal ESD-garment all ESD risks are excluded, supposing that the garment is also used properly.

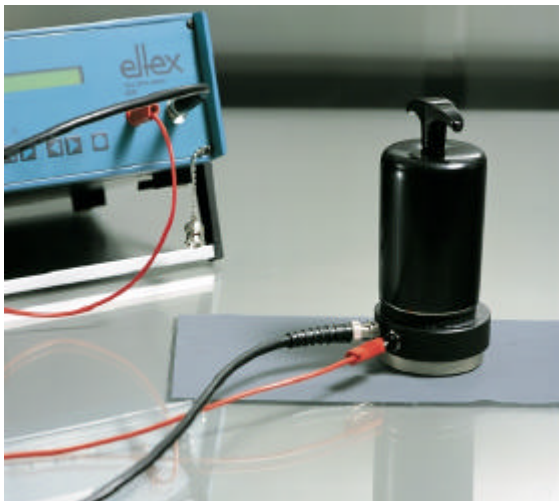
4. Standard test methods

The standard test methods for ESD-protective fabrics and garments used in electronics industry are resistive [3,4]. Surface resistance or resistivity of the material is measured by using cylindrical electrodes, originally developed for the characterization of homogeneous packaging materials, see Fig. 3. Measurement of point-to-point resistance is also recommended. For garments the most important standard test is the measurement of point-to-point resistance, which can be done from sleeve to sleeve, from sleeve to hem, etc, see Fig. 4. The resistive tests are easy to make, and when the garments were made of homogeneous fabrics they were also reliable. Many other methods have also been proposed for the evaluation of ESD protection performance of ESD garments, some are applicable others are not. A good state-of-the-art review of the subject is given in ref. [6].

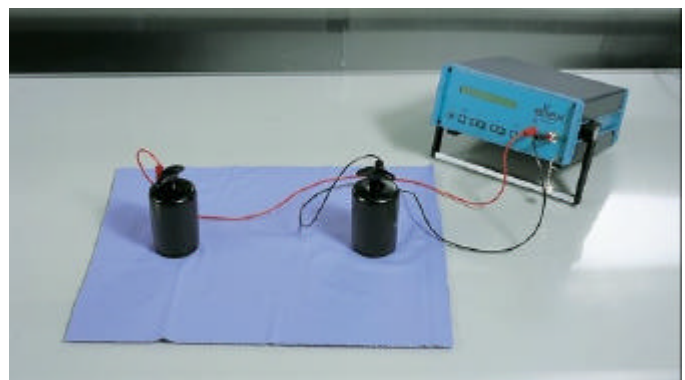
The problem of present standard test methods is that they do not fully satisfactory qualify the effectiveness of novel ESD-protective garments. Too often they measure only the electrical performance of the net formed by the conductive threads. Current practice resistive measurement techniques do ignore potentially important factors such as:

- * the effect on performance of grounding the conductive garment elements,
- * the risks introduced by unearthed conductive fibres as a possible source of ESD,
- * possible charge storage and ESD risk arising from insulating areas of a heterogeneous fabric,
- * the possible penetration of electrostatic fields from undergarments through the fabric,
- * triboelectric propensity.

Additionally, the adoption of resistive measuring techniques with core conductive fibre fabrics easily can lead to the rejection of a fabric or garment for inappropriate reasons. This is simply because the measuring electrode will not be in contact with the conducting fibre but with the insulative surface of the conducting threads. Similar lack of good electrical contact between the electrode and conductive fibre, leading to inappropriate rejection of a product, can happen also in the case of other types of composite threads when using resistive methods. As already said, all the given factors may not be of real risk but they cannot be excluded without a study.



(a)



(b)

Figure 3 Measurement of surface (a) and point-to-point (b) resistances according to the IEC 61340-5-1.

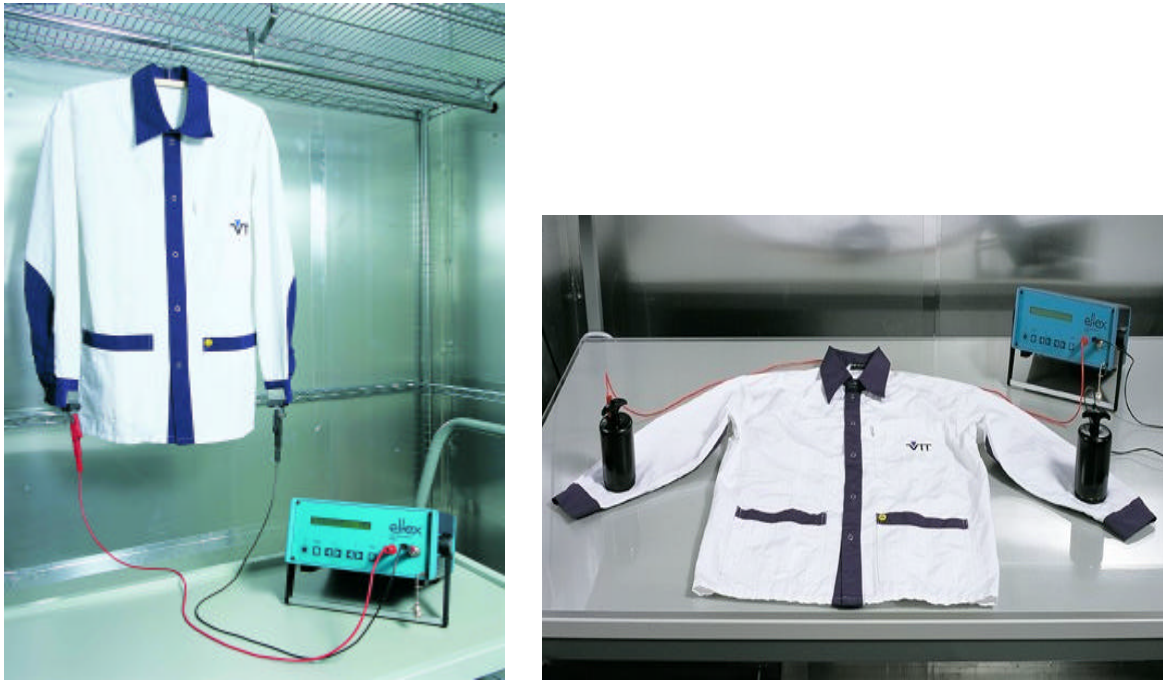


Figure 4 Measurement of point-to-point resistances of ESD garments according to the ESDA and IEC standards.

5. Future plans of the project

In the ESTAT-Garments project the development of new or modification of existing test methods is backed by fundamental research and studies. During the first half of the project we will: 1) identify and quantify different types of electrostatics threats caused by clothing to sensitive electronics, 2) elucidate the behaviour of charges on composite textile surface, 3) study the electrostatic interrelations between the components of the system composed of operator - ordinary clothing - protective garment-sensitive electronics, 4) characterize the material and construction of different kinds of ESD-garments and 5) characterize the electrostatic properties of ESD-garments. Then the findings will be collected and transformed to a new test method(s) or an existing method will be modified. The verification of the methods will be done by interlaboratory tests. Final results should be available in spring 2005.

6. Conclusion

An European research project "Protective clothing for use in the manufacturing of electrostatic sensitive devices (ESTAT-Garments)" is running with an aim to give a basis to qualify the effectiveness of clothing used for the ESD-safe handling of ESD sensitive (ESDS) devices and to develop appropriate test methods for the characterisation of such ESD protective garments. The results should be available in 2005.

Acknowledgements

This work is supported by the European Commission, Contract No. G6RD-CT-2001-00615.

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