Electrostatic testing of ESD-protective clothing for electronics industry

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- Sensitivity of components to ESD
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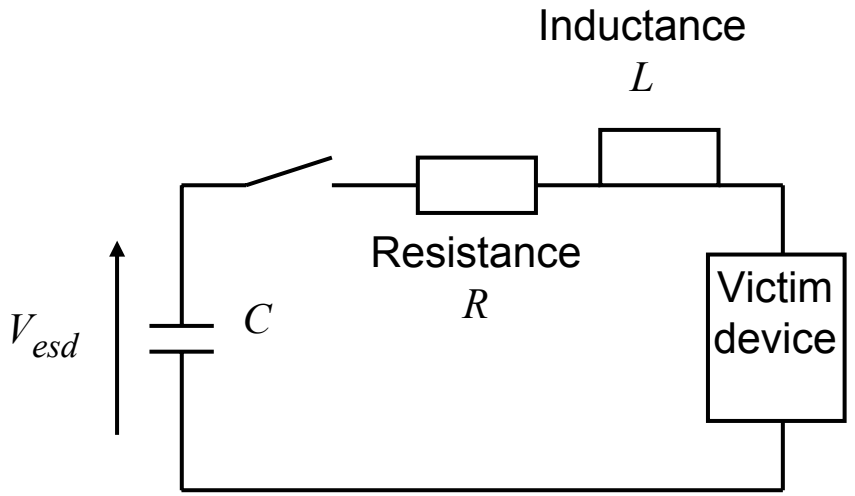
ESD models

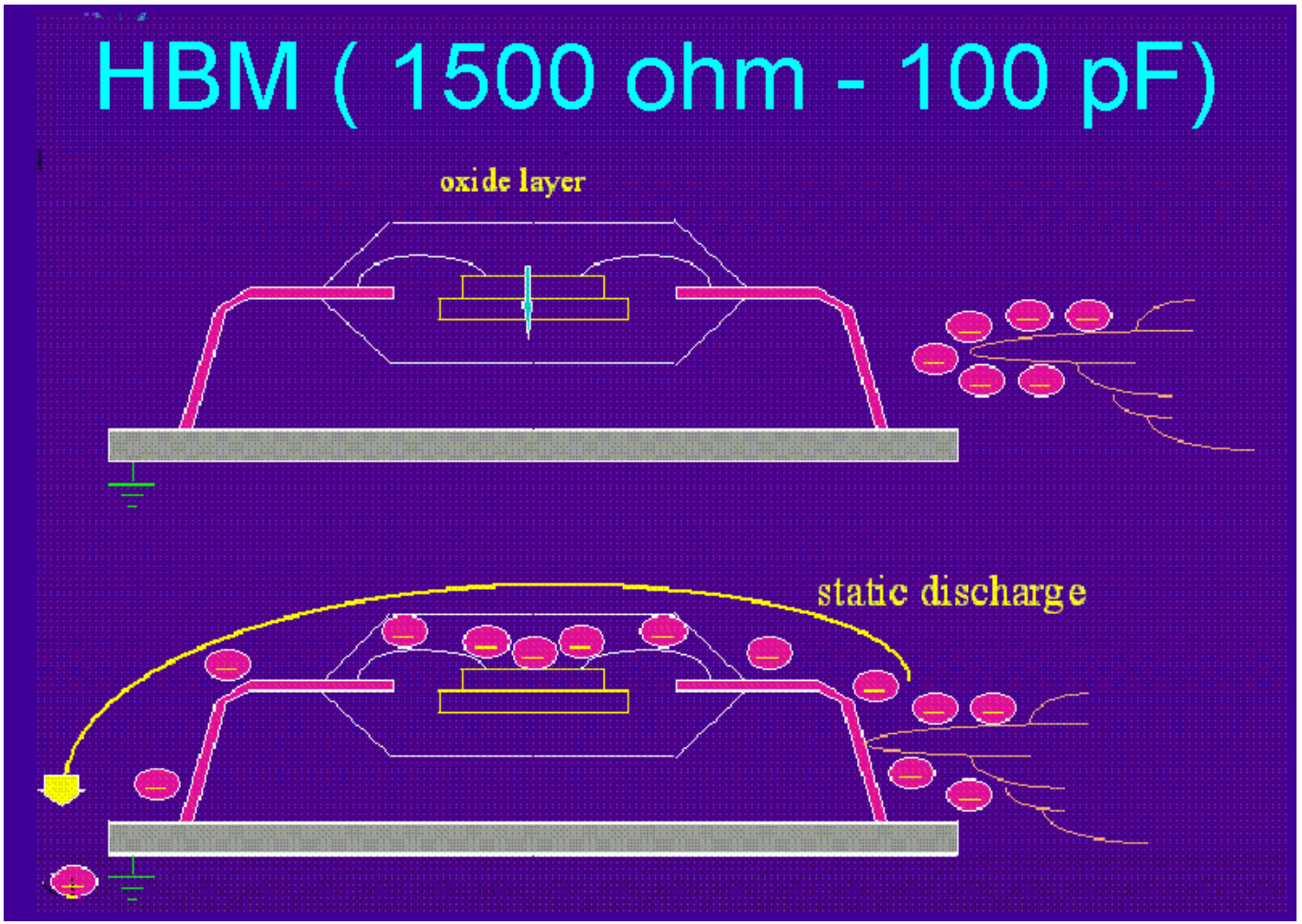
- Waveforms of electrostatic discharges (ESD) are highly variable.
- The waveform - rise time, peak current, duration - is strongly influenced by the electrical characteristics, geometry and dimensions of the materials in the discharge circuit, the level of initial charge, the speed of approach of the contacting ‘electrode’, etc.
- Practical need has led to the development of three standardised ESD models:
  - **Human Body Model (HBM)**
  - **Machine Model (MM)**
  - **Charged Device Model (CDM)**

ESD models

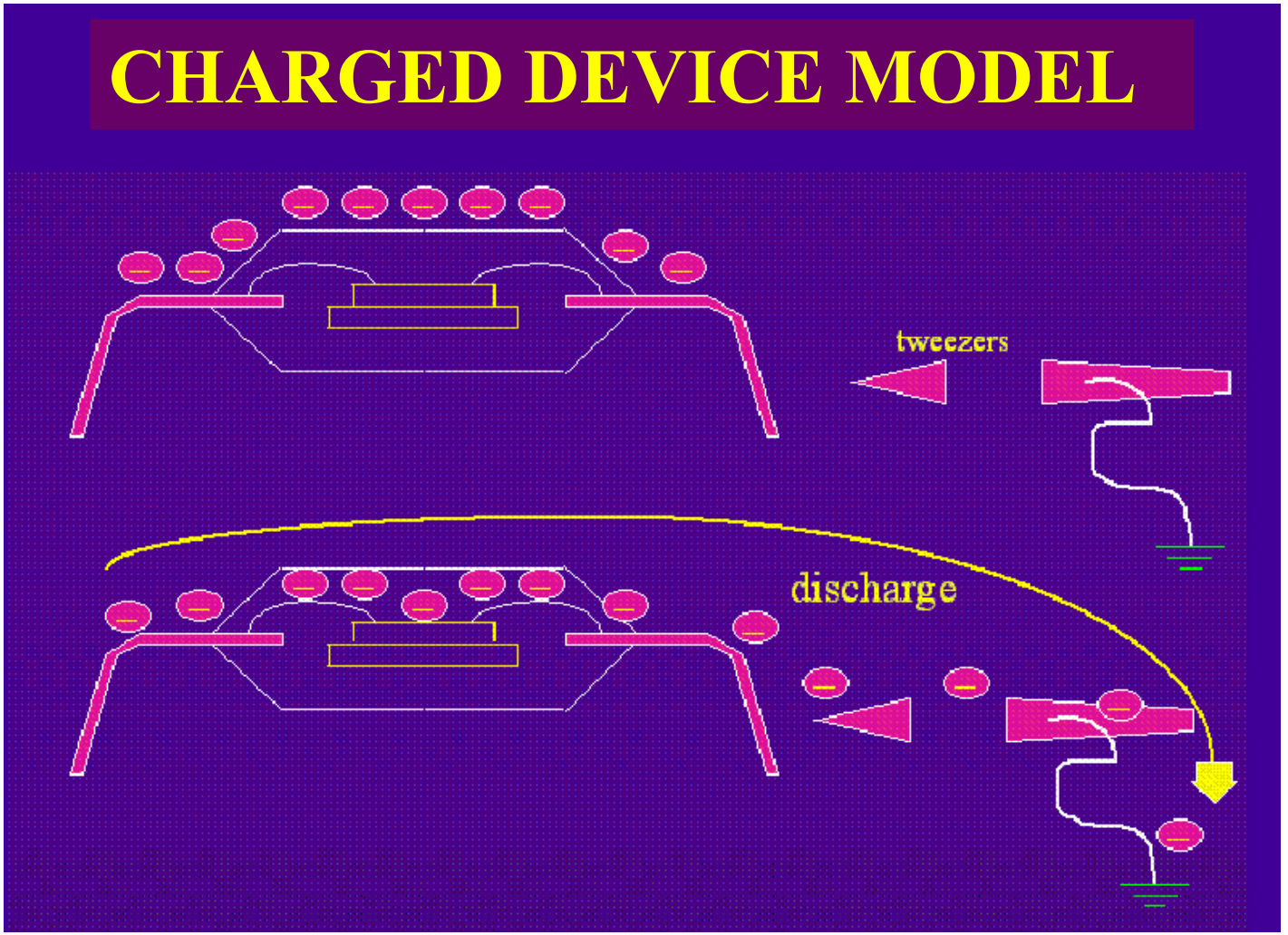


Model	*R* (Ω)	*C* (pF)	*L* (nH)
Human body model HBM	1500	100	stray
Machine model MM	stray	200	stray
Charged device model CDM	< 10	Capacitance of device under test (1-30pF)	< 10

ESD models



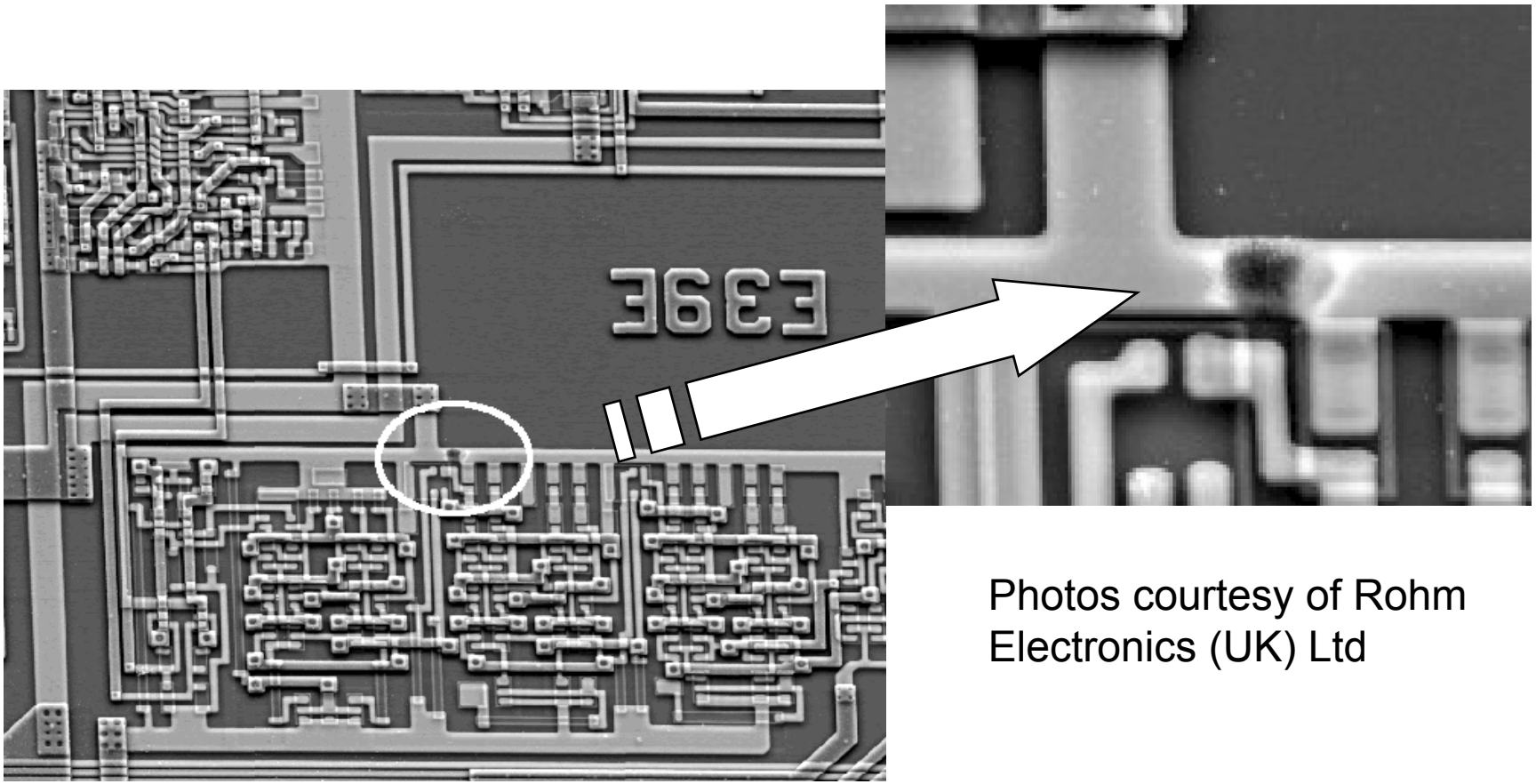
ESD models



Sensitivity of components to ESD

- Progress in semiconductor industry has led, as a side-effect, to devices which are more sensitive to electrical disturbances than ever before.
- About 30-50 % of all failures in electronic products detected during manufacturing can be attributed to some kind of electrical overstress, of which electrostatic discharge (ESD) is one type.
- An ESD failure of a device may appear instantly or it may fail later (latent failure).
- ESD failure can be caused either by the discharge energy or power or by an internal overvoltage due to the ESD.

Sensitivity of components to ESD



Photos courtesy of Rohm Electronics (UK) Ltd

Example of an ESD damage to an IC

Sensitivity of components to ESD

- Sensitivity of electronic components to ESD is typically given as **ESD withstand voltage** which is the largest ESD voltage, according to a standard ESD model, that the device can stand without a damage.
- ESD sensitivity of many components is in kV-range (HBM) but the number of ultrasensitive devices with ESD sensitivity even below 100 V is rapidly increasing.
- Most sensitive components are
  - MR heads
  - RF devices (especially discretes)
  - some optoelectronic devices

Sensitivity of components to ESD

- Many ICs have on-chip protection networks.
- Some devices cannot be protected
  - trade-off against performance
- Human being cannot feel an ESD below 2-4 kV.
- An operator or production equipment can easily charge up to several kV if correct ESD protective measures are not taken.

ESD-protective clothing

- The main purpose of ESD-protective clothing (ESD-garments) is

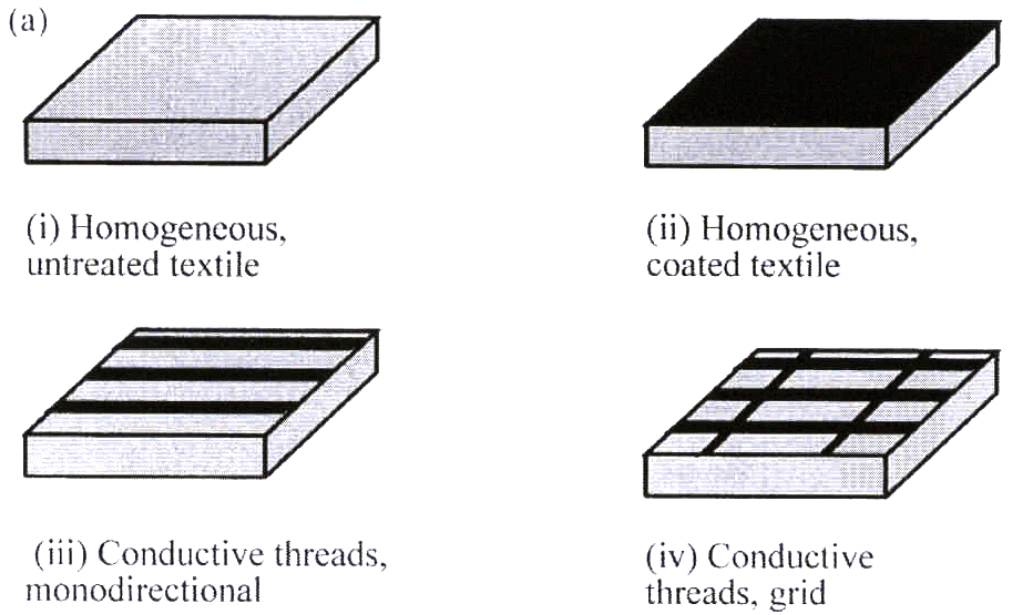
  to protect sensitive electronics from failures of electrostatic origin.

- ESD garment is worn over the ordinary clothing of the operator and can have also other functions (cleanroom garments).

ESD-protective clothing

- Requirements of electronics industry have resulted in that modern **ESD garments are made of heterogenous composite fabrics** where a grid or stripes of conductive threads are present inside an insulating matrix of cotton, polyester or mixtures of these materials.
- The conductive threads are more and more frequently made by composites, i.e. by a mixture of conductive and insulating fibres.
- There are several variations in both fabric and thread structures.

Modern ESD-textiles



(a) Structures of homogeneous and heterogeneous textiles

(b) Structures of commonly used conductive fibres

ESTAT-Garments project

- It is not certain that the present standard test methods for garments used in electronics industry indicate how much the garments will protect the electronics from ESD.
- Therefore the European Commission, to support IEC TC101, issued a call for a research about a new test method for ESD-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.

ESTAT-Garments project

- The **main goal** of the three-years project (2002-2005) is to supply the standards body IEC TC101

1. with **a basis to qualify the effectiveness of clothing** used for the ESD-safe handling of ESD sensitive (ESDS) devices and
2. **to develop appropriate test methods** for the characterisation of such ESD protective garments.

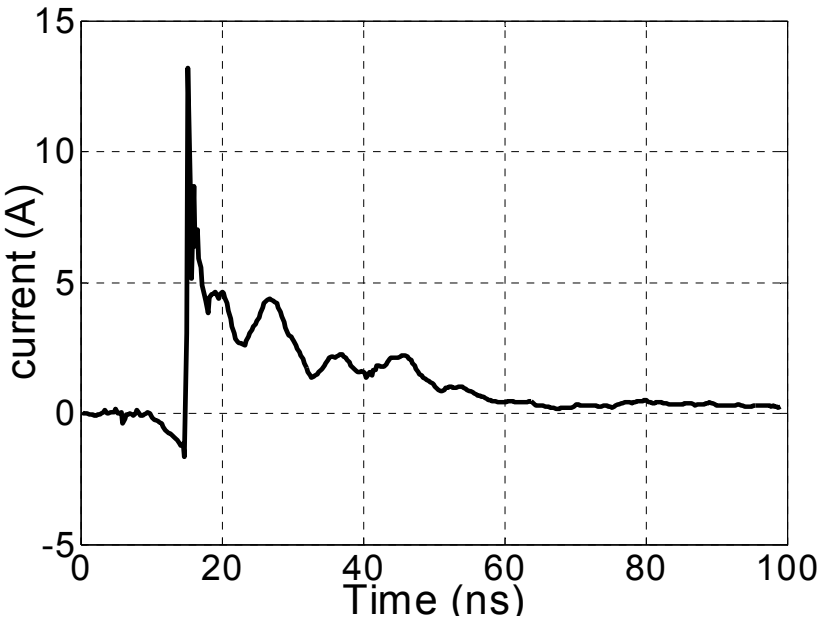
How garments could damage electronic components?

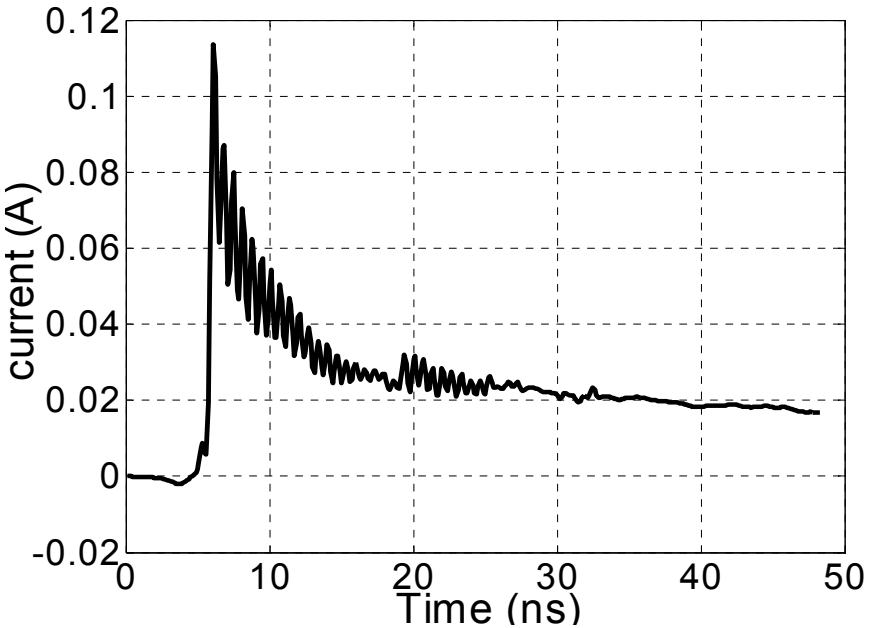
- An ESD failure caused by charged operator or charged clothing can potentially happen in three different ways:

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 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 an ESD (CDM ESD).
3. by **radiation** (damage by electromagnetic pulse due to nearby ESD) but strong ESD is required for a failure.

- A damage will happen in an ESD if the withstand level of the victim component is exceeded.

How garments could damage electronic components? - Direct discharges

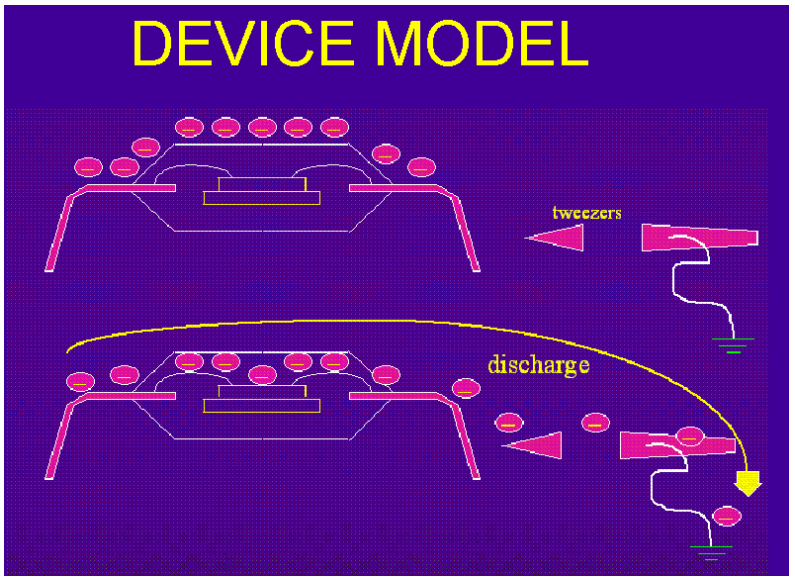




Examples of direct discharge currents from two unearthed ESD fabrics charged to 2 kV: stainless steel threads (left), carbon based threads (right)

How garments could damage electronic components? - Discharge from charged device

- A device may become charged in an electrostatic field arising from the garment.
- Electrostatic fields external to the garment may be dependent on
  - rate of charging or charge dissipation of the garment materials
  - ability of the garment material to shield the electrostatic field of underlying garments
  - suppression of fields by coupling to the body of the person wearing the garment.



• A device may become charged also by accidental rubbing of the package against the garment material.

Requirements for electrostatic testing of ESD garments

- The main purpose of ESD-garments is to protect sensitive electronics from ESD failures.

- An **ideal ESD garment** possess all the desired properties:

1 Low resistance (fast dissipation)

2 High resistance (safe slow dissipation and electrical safety)

3 Total suppression of electrostatic fields from charge under and on an ESD garment surface

4 An anti-static material that does not generate a charge when contact is made to any other material

Requirements for electrostatic testing of ESD garments

- The purpose and the ideal properties of ESD garments should be taken into account when evaluating test methods for ESD protective clothing.
- **Any good test method for ESD protective clothing should assess garment's ability to provide ESD protection.**

Requirements for electrostatic testing of ESD garments

- Electrostatic testing of ESD garments should potentially take into account the following factors:
  - triboelectric propensity of the fabric
  - 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 normal clothing under the ESD garment

Requirements for electrostatic testing of ESD garments

… cont. (Electrostatic testing of ESD garments should potentially take into account the following factors)

- the influence of grounded operator wearing the garment on the protective performance of the garment
- integrity of seams
- resistance experienced by the charge in the ground path
- resistance of an ESD garment from electrical safety point of view
- capacitance experienced by the charge on the garment material
- ....

Requirements for electrostatic testing of ESD garments

- The list of factors together with an assessment of risks of damage to electronics with reference to garments are used when
  - evaluating existing electrostatic test methods
  - developing new method(s), if necessary.
- Evaluation of existing methods within the ESTAT-Garments project is running and should be completed in September 2003.

Recommendations for ESD garments

- Reliable grounding seems to be very necessary for ESD garments.

⇒Special recommendations for the grounding will be required, at least when handling very sensitive devices.

- In the future there may be a need for classification of ESD garments according to their ESD protective performance.

Recommendations for ESD garments

Example of possible future classification of ESD garments for a given relative humidity

Garment class	Targeted protective use	Required garment performance and structure
Class 1	Ultrasensitive devices	High protection level; special recommendations for grounding, garment structure, use etc.
Class 2	ESDS with >100 V withstand	Normal protection level corresponding to typical state-of-the-art ESD garments
Class 3	ESDS with >2 kV withstand	Low requirements for the electrostatic performance, some normal garments may pass the requirements
NB. This classification is presented only to promote discussion		

Conclusions

- Progress in semiconductor technology has led to devices which are more sensitive to ESD failures than ever before.
- There are a few branches of electronics industry, such as rf-electronics, where the number of ultra ESD-sensitive devices is expected to grow from the present, already relatively high level.
- Effective ESD protective measures are required, covering production personnel, equipment and systems, to avoid production losses due to ESD as well as product problems due to latent failures.

Conclusions

- An European research project ”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.

- Further information on the ESTAT-Garment project and its results is available at

http://estat.vtt.fi