# IEC TR 61340-5-5

Edition 1.0 2018-11

# TECHNICAL REPORT



## Electrostatics –
## Part 5-5: Protection of electronic devices from electrostatic phenomena – Packaging systems used in electronic manufacturing



IEC TR 61340-5-5:2018-11(en)

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colour inside

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 17.220.99; 29.020 ISBN 978-2-8322-6255-9

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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# ELECTROSTATICS –

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IEC TR 61340-5-5, which is a Technical Report, has been prepared by IEC technical committee 101: Electrostatics and IEC technical committee 40: Capacitors and resistors for electronic equipment.

The text of this Technical Report is based on the following documents:

| Draft TR | Report on voting |
|---|---|
| 101/564/DTR | 101/575/RVDTR |

Full information on the voting for the approval of this Technical Report can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61340 series, published under the general title *Electrostatics*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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# INTRODUCTION

Packaging materials used within an electrostatic discharge (ESD) control programme often are defined by an electrical resistance measurement. Packaging material manufacturers rely on industry standardized test methods to ensure that the materials they supply meet industry defined specifications. However, other attributes provided by a packaging material often are difficult to quantify, leading to confusion between packaging material manufacturers and the end users.

Increased use of automated handling equipment for the manufacture of electronic products has resulted in changes in the design and form of packaging materials that contain electronic parts and components. In particular, very small profile parts such as surface mount resistors and capacitors are contained within pocket tape reels that are unloaded by automatic equipment. Small dimension parts require small dimension packaging materials. Small dimension packaging materials cannot be evaluated for electrical properties by the existing industry accepted test methods.

Several types of packaging are used within the electronics industries that do not have the basic properties generally associated with electrostatic control, such as paper tape. Industry best practices involving these standard packaging material forms are discussed. Other forms of packaging for non-ESDS (electrostatic discharge sensitive items) that are brought into the ESD protected area (EPA) and considerations for handling such packaging forms are described. This document has been prepared by a joint working group so that the considerations of electrostatics and the application of protective measures are compatible with the concerns of those who provide or use small dimension electronic components.

# ELECTROSTATICS –

# Part 5-5: Protection of electronic devices from electrostatic phenomena – Packaging systems used in electronic manufacturing



## 1 Scope

This part of IEC 61340 discusses packaging material requirements for electrostatic discharge sensitive items (ESDS) as well as non–ESDS which can apply to packaging materials such as embossed carrier tape, trays, tubes (stick magazines), rails and others used in back end line processing and parts handling where test methods described in other standards are, for the most part, inadequate. Issues related to electrostatic charge generation, electrostatic attraction and repulsion are included. The recommendations and discussions within this document can also be applicable to other types of packaging that cannot be evaluated by other means.

This document discusses the issues related to

1) technical considerations for packaging material selection and packaging system design,
2) packaging material specifications for electrostatic control,
3) existing test methods and their limitations for packaging materials,
4) suggestions for the evaluation of small dimension packaging materials, and
5) industry common practices.

## 2 Normative references

There are no normative references in this document.

## 3 Terms, definitions and abbreviated terms

### 3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

**3.1.1**
**electrostatic protective packaging**
containers and other enclosures that have properties and functionality to limit electrostatic charge generation, dissipate electrostatic charge, or limit interior electrostatic fields

**3.1.2**
**intimate packaging**
materials that come into direct contact with ESD sensitive items

**3.1.3**
**proximity packaging**
materials or items that cover or surround intimate packaging materials

**3.1.4**
**conductive material**
material with surface or volume conductive properties generally specified by electrical resistance lower than dissipative materials

**3.1.5**
**dissipative material**
material with surface or volume conductive properties with an electrical resistance greater than conductive materials but less than insulative materials

**3.1.6**
**insulative material**
material with electrical resistance high enough to impede charge flow to some degree

**3.1.7**
**low charging**
antistatic
property of a material that limits electrostatic charge transfer by contact and separation (triboelectrification)

**3.1.8**
**surface resistance**
ratio of DC voltage to the current flowing between two electrodes of specified configuration that contact the same side of a material

Note 1 to entry: Surface resistance is expressed in Ω.

**3.1.9**
**surface resistivity**
for electric current flowing across a surface, ratio of DC voltage drop per unit length to the surface current per unit width

Note 1 to entry: In effect, the surface resistivity is the resistance between two electrodes on the opposite sides of a square and is independent of the size of the square or its dimensional units.

Note 2 to entry: Surface resistivity is expressed in Ω. It is common practice to express surface resistivity in ohms/square to distinguish from surface resistance.

**3.1.10**
**volume resistance**
ratio of the DC voltage per unit thickness to the amount of current per unit area passing through a material

Note 1 to entry: Volume resistance is expressed in Ω.

**3.1.11**
**electrostatic discharge shielding**
materials that attenuate an electrostatic field and limit energy penetration induced by an electrostatic discharge

**3.1.12**
**electrostatic field shielding**
materials that attenuate an electrostatic field

## 3.2 Abbreviated terms

CDM charged device model

CPM charged plate monitor

EPA ESD protected area

ESD electrostatic discharge

ESDS electrostatic discharge sensitive item

HBM human body model

## 4 Role of electrostatic protective packaging

### 4.1 Analysis of electrostatic risks (what can cause problems to ESDS)

The risk to electronic parts, assemblies and equipment (collectively referred to as "ESDS") from electrostatic phenomenon takes several forms and can be summarized as direct electrostatic discharge from a charged conductor to the ESDS or electrostatic discharge from the ESDS to another conductor (at a different potential) or ground if the ESDS becomes excessively charged. Damage to an ESDS will always be the result of an excessive flow of current through the ESDS.

It is necessary to note that the transfer of electrostatic charge (separation of charge) will happen every time two materials come into contact and separate. The resulting separation of charge will yield an equal positive and negative charge on the opposing surfaces. The differences in interactions include how much charge is separated and where the charge goes after it is separated, which is controlled by the electrical properties of the material. Charged materials with the ability to conduct electricity can be neutralized (charge dissipation) by contact with ground (earth). The rate of this charge neutralization/dissipation is controlled by the electrical resistance of the material and the contact resistance between the material and ground. The higher the resistance of the material and its contact resistance to ground, the longer it will take to come to charge neutrality. A positively charged material will gain missing electrons from ground while a negatively charged object will drain electrons to ground.

The amount of discharge an ESDS can tolerate is determined by a number of factors including part sensitivity, assembly layout, rate of the charge transfer through the ESDS, total energy in the discharge and environmental influences.

Discharge to an ESDS can occur by contact from a charged conductor, including a person, machine component, tool or fixture or any other charged conductor involved in a process. Reducing the probability of a damaging discharge to an ESDS is one of the principle methods of electrostatic control. The risk of damage from charged conductors is reduced when all the conductive materials and items are electrically bonded to ground. A grounded conductor cannot hold an electrostatic charge.

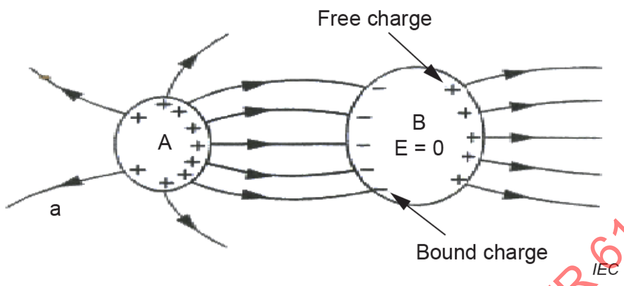
Discharge from a charged ESDS to ground is controlled by reducing the charge accumulation on the ESDS itself. Once an ESDS is charged, it is difficult to remove the charge without some risk of excessive current flow through the ESDS. Therefore, one of the key factors in packaging design is to reduce the charge generation propensity between an ESDS and the container used for storage and shipment.

Charge generation cannot be reduced to "zero" but can be limited to below the threshold that will cause excessive risk to the ESDS by the design of contacting surfaces, chemical changes or additives placed in materials to alter surface charging characteristics and usually by providing some level of electrical conductivity to allow charges to dissipate.

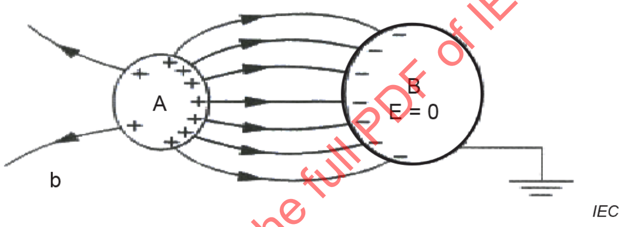
### 4.2 Charge generation (separation)

Triboelectric charging is the primary way that materials become charged. This process is described by the actions of contact between dissimilar materials and then their separation. The resulting charge level is influenced by the intimacy of contact, the speed of separation and any rubbing motions that can be part of the contacting process before separation. The physical properties of the surfaces of the contacting materials also influence the charging process. Reducing the surface area of contact is one of the ways that triboelectric charging can be reduced. Chemical additives to the material surfaces can also reduce charge generation by decreasing the friction between the surfaces. Adding dissipative agents can allow charges to spread out on surfaces or dissipate when in contact with ground thus reducing the concentration of charge.

Charging by induction occurs when a conductive item is grounded while in the presence of an electric field. While this is a complex phenomenon, it can occur where ESDS are handled in both manual and automated processes if the electrical fields on materials in the environment are not maintained below critical levels (determined by ESDS sensitivity). The first step in the induction process occurs when an ESDS is brought into an electrical field. Charges realign within the ESDS by polarization as shown in Figure 1 a). At this point, there is no charge separation within the ESDS, only polarization.




**a) Isolated conductor B polarized in the presence of electric field A**

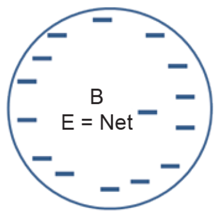



**b) Conductor B grounded in the presence of electric field A – resulting in trapped charge on B.**

**Figure 1 – Induction charging process – Grounding a conductor in the presence of an electrical field**

If the ESDS is connected to ground while in the electric field, charge will flow to or from ground depending on the polarity of the charge on the conductive portion of the ESDS. This is the first discharge that occurs as shown in Figure 1 b).

If the ground connection is terminated before the electrical field removed from the area (this happens when the part moves along in a process), a charge will be trapped on the ESDS as shown in Figure 2 a). If another ground contact is made on the charged device, a second discharge occurs that neutralizes the charge on the object, as shown in Figure 2 b).

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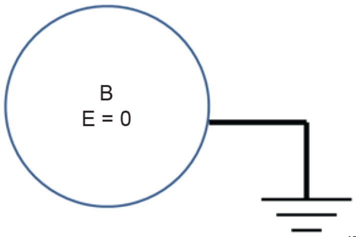
**a) Charged device B after disconnecting from ground shown in Figure 1 b)**

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**b) Discharge of charged device B by contact with ground**

**Figure 2 – Second part of induction charging process**

Actual discharge pulses from an experimental induction process are shown in Figures 3 and 4. As can be readily observed, there are nearly equal and opposite polarity discharge events in each induction charging-discharging process.


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**Figure 3 – First discharge pulse that occurs as shown in Figure 1 b)**


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**Figure 4 – Second discharge pulse that occurs as shown in Figure 2**

If the structure of an ESDS is very small, the induction from an electric field may result in internal voltage levels high enough to damage the ESDS. The critical voltage level depends on the breakdown voltage of the insulating layers within the ESDS.

Charging by contact with a charged object can occur if the previously uncharged conductive parts of an ESDS contact another conductor at a different potential. Charge sharing will occur between conductors in this manner. The charge will discharge when the ESDS is connected to ground, the same as the process shown in Figure 2 or by contact with an item with larger capacitance and low resistance. There is a risk of damage if the current flow in the discharge is over the ESDS sensitivity threshold.

### 4.3 Reduction of electrostatic charging items in the environment

The first step in reducing the risk of electrostatic damage in any process environment is to make sure that all the electrically conductive or dissipative items and materials within that environment are connected to ground or at least bonded together to share charge and equalize electrical potential. ESDS can be handled with low risk from electrostatic discharge if handled within the environment with equalized electrical potential.

The second step is to remove all unnecessary non-conductors (insulators) from the process environment since the electrostatic charge on those materials cannot be dissipated by grounding. If an insulative material is not needed in the process, it should be removed. The electrical field strength where unprotected ESDS are handled shall not exceed 5 000 V/m. Process essential insulators with surface electrostatic fields greater than 2 000 V at 2,5 cm should be kept 30 cm away from the ESDS or the electrostatic field reduced to < 125 V at 2,5 cm for close proximity applications (< 2,5 cm). It has been shown experimentally that the size of a charged insulator, the distance of separation from an ESDS, and the field strength all should be considered in any risk assessment.

The third and most challenging step in reducing the process risk to ESDS is to reduce the charge accumulation on the parts themselves. Since the contact and separation of the ESDS from any surface can potentially cause charging, care should be taken in the evaluation and selection of contacting materials, which includes packaging materials used for storage and shipment.

The amount of charge that an ESDS can tolerate is the subject of much speculation and discussion that is likely to continue for some time. The most logical assumption is that charged device model (CDM) testing determines the sensitivity of a given ESDS to the defined CDM discharge waveform and therefore an equivalent amount of charge measured on the actual ESDS should be considered as a risk level for damage. Some relatively simple and well understood charge measurements can be made on an ESDS, the capacitance of the ESDS determined, and the voltage as well as stored energy calculated to compare to the ESDS CDM failure threshold. While the direct relationship between the CDM and the actual charge on an ESDS in a process might not be 1 to 1, the risks for damage can be better understood in a process assessment so that the charging level threshold can be set. Managing the charge generation on an ESDS can be monitored with a variety of instruments including contact and non-contact electrostatic voltmeters and perhaps field meters if the ESDS is large enough in area. It is likely that the most useful measurements will be made with a Faraday cup or pail where the charge in coulombs is measured directly.

### 4.4 Electrostatic attraction and repulsion issues

One of the most important principles in electrostatics is that opposite sign charges attract and same sign charges repel. The actual force that is present in attraction and repulsion is determined by the charge on the involved items or materials and the resulting electric field. The higher the charge, the stronger the electric field, and the stronger the attraction or repulsion forces. This basic principle of attraction and repulsion is used throughout industry and affects almost any activity that comes to mind. The copy machine in an office would not work without this fundamental principle. Filters that clean the air in industrial processes would lose efficiency without this principle. There are countless other activities that rely on this simple law of physics that is learned in primary school around the world.

This simple and well-known law of physics also is the cause of countless problems in industry due to unwanted attraction or repulsion. Electrostatic charge and the resulting electric fields cause dust attraction in a semiconductor wafer fabrication facility that can ruin electronic parts while they are being imaged. Electrostatic attraction or repulsion can cause parts to not feed correctly in automated handling equipment during circuit board assembly. Small profile parts such as capacitors and resistors can be physically influenced by electric fields that would be considered weak or inconsequential in many other applications.

The electric field requirements stated above in 4.3 might not be sufficient to reduce small part clinging or attraction. Further reduction of electrostatic field strength can be necessary when handling very small parts. Fortunately, the proper use of ionized air and the selection of low charge generating packaging materials can help mitigate these small parts handling issues.



## 4.5 Dissipation of electrostatic charge

As mentioned in 4.1, electrostatic charge will dissipate or become neutralized by different mechanisms, depending on the materials involved. Materials or items with some level of conductivity will dissipate or lose their net charge by contact with ground. The rate of this charge dissipation is controlled by the actual electrical resistance and capacitance involved in the discharging circuit. For the purposes of packaging materials, the electrical resistance can be relatively high on the surface of the material. Most of the standards call for a surface resistance test method to measure packaging materials. The actual methods that are used vary depending on the shape of the material and are discussed in Clause 6.

Electrostatic decay is one of the forms of charge dissipation that is used to determine the upper limits of functionality for packaging materials. In concept, electrostatic decay is a measurement of the time it takes for a sample under test to lose or equalize a defined portion of charge when the sample is grounded. The electrostatic decay methods are discussed in Clause 6.

## 4.6 Barrier to ESD current

Limiting or ideally preventing an electrostatic discharge from entering a packaging material containing electrostatic discharge sensitive (ESDS) items is a function of an electrical property known as insulation. Electrical insulation limits current or charge flow by definition and the importance of insulation in electrical terms cannot be understated. Unfortunately, insulating materials are also prone to gaining and holding electrostatic charge. One of the primary packaging materials used in the protection of electronic items is electrostatic discharge shielding. These are generally laminated materials, with one layer being an insulator or at least a high resistance dissipative material to limit current flow through the package, a highly conductive material to provide electrostatic shielding and an interior layer that has low charging properties.

## 4.7 Protection against electrostatic fields

An electrostatic field will pass through electrical insulation, so insulation alone cannot prevent charging by induction to susceptible items that might be contained within an insulating package. Attenuation of an electric field requires an enclosure made from conductive materials. The actual amount or level of shielding provided by a package is determined by the conductivity of the material, the thickness of the conductive layer and the separation distance from the exterior of the package to the contained susceptible item. Shielding is a dynamic property and therefore the test methods tend to become complicated as discussed in Clause 6.

## 4.8 Chemical and outgassing issues

Sometimes cleanliness issues are more important than the electrostatic issues, especially for intimate packaging materials – those that come into direct physical contact with the item being packaged. Unfortunately, adding the necessary chemicals to provide electrical dissipation or low charging properties can impact the cleanliness of the packaging material and cause unwanted or damaging contamination to the contained items. Balancing the electrostatic and contamination issues is often difficult.

### 4.9 Moisture barrier

Some electronic parts are subject to moisture attenuation (device package/body absorption) and should be stored and transported in moisture barrier materials. Generally, these are bag type products that have a laminated structure, with one of the layers being metallic foil or very heavy vapour deposited metal (normally aluminium). Moisture barrier materials should be sealed to form the impervious barrier, often after evacuation of the contained air and/or backfilling with specially dried gases such as nitrogen. Desiccant packets or pouches can be added to attenuate moisture trapped inside the sealed bag.

### 4.10 Environmental conditions affecting packaging materials

Protecting electronic parts and other susceptible items from atmospheric conditions is an important role for packaging materials. The moisture content of the air can have an influence on the charge generation, charge dissipation and even the insulative properties of packaging materials. High and low temperature extremes can have deleterious effects on the physical and chemical characteristics of packaging materials. It is important to understand the storage and transportation situation when selecting or designing packaging materials or systems.

### 4.11 Packaging material principles

#### 4.11.1 General

A key to selecting or designing the appropriate packaging material for any given application involving electrostatic control is to understand the fundamentals related to the material properties. These properties are summarized below.

#### 4.11.2 Low charging

Low charge generation is the main consideration for those packaging materials that will come into intimate contact with the contained items. The low charging property is also the most difficult to specify since there are very few, if any, universally accepted test methods. There are many demonstrations, application specific procedures and simple manipulations that have been prepared and used by practitioners over the years that evaluate the charge generation process. However, there are no intrinsic tests for the low charging property. It is equally difficult to assign an electrostatic charge or electric field value that will gain universal acceptance as a specification. Most often the charge level is intuitively recognized by the electric field emanating from that charge on the surface of a material. A useful specification is the field strength limit set in IEC 61340-5-1 at 5 000 V/m (equal to 50 V/cm). An electric field strength of 50 V/cm is a reasonable starting point for establishing a low charging specification. Some applications where very small parts are handled can require a lower value but the value can be adjusted as needed by the user. However, measuring the electric field on small profile packaging materials or other items with any defined accuracy is another matter that will be discussed later.

#### 4.11.3 Electrostatic charge dissipation

Electrostatic charge dissipation is a major property that has usefulness in packaging materials. The ability of a package to lose charge by grounding or by contact to a grounded person who is handling the package is an important property. If the package does not hold a charge and the interior of the package has not contributed to charge generation then it is unlikely that the contained items will have any significant charge. It is important for the package to lose charge before opening the packaging and removing the contents to avoid bringing the contents through a changing electric field. The upper limit for surface resistance to qualify as a dissipative material is $< 1 \times 10^{11}$ Ω as measured by the surface resistance method described in 7.3. Extreme care is needed when specifying dissipative materials since the electrical range is huge. The functional performance is vastly different at the extremes of the dissipative range. Materials with surface resistance at $1 \times 10^{5}$ Ω have a very different decay rate than materials at 9,9 x $10^{10}$ Ω. Therefore, care is needed when reading packaging material data sheets as the term "dissipative" should have an assigned resistance value in order to provide clarification of where the material falls within the range.

#### 4.11.4 Conductive materials

Conductive materials are used in packaging systems particularly when grounding of the package is extremely important or the items contained are of an energetic or explosive nature. Flexible conductive packaging has significant use in chemical, munitions, and other hazardous material handling applications. Packaging systems for electronic products most often use conductive polymer-based materials for rigid and semi-rigid containers. Surface and volume resistance test methods are discussed in 7.3. Specifications for conductive materials are set in standards generally at ≤ 1 x $10^5$ Ω, although IEC 61340-5-3 sets the limit at < $10^4$ Ω. There is no lower limit so metallic containers with very low electrical resistance fall into this category although there is a subset in the conductive range that is defined as electrostatic field shielding.

#### 4.11.5 Electrostatic field shielding

Electrostatic field shielding describes those conductive materials that are generally ≤ 1 x $10^3$ Ω. Heavily filled polymers (carbon, silver, copper and some of the newer nano-technology fillers) and metal structures are included in this category. Electrostatic field shielding will attenuate electric fields but may not protect against discharge currents from passing through the wall of a container made from the highly conductive materials. The thickness of the wall of the enclosure made from conductive materials influences the discharge current in the event of a direct ESD event.

#### 4.11.6 Electrostatic discharge shielding

Electrostatic discharge shielding is the term that describes a multi-layer, packaging material, normally in bag form, that includes many of the previously discussed desirable properties for protection of electronic parts. The interior of an electrostatic discharge shielding bag is usually a low charging and dissipative surface that is intended to limit the charging of the contained items during contact and separation that occurs when items are placed inside the bag or when they move around in the bag during shipment. Most often the specification for the interior will be electrical resistance based on a surface resistance test. Typically, the acceptable value is < 1 x $10^{11}$ Ω. The electrostatic discharge shielding bag contains an insulating layer to limit current flow through the wall of the bag. The layer is thin, generally 25 µm to 50 µm so the dielectric strength is limited but sufficient for most plausible electrostatic discharge events a package is likely to experience in transportation or storage. A thin layer of metal is deposited on the insulator surface to form the electrostatic shielding layer. The layer normally will have at least some transparency to allow visual verification of the contained items. Since the shielding layer is thin enough to be transparent, the actual level of shielding is limited. Thicker materials, usually without transparency, are often equipped with an additional layer which has a water vapour barrier for the transport and storage of moisture-sensitive components. Industry experience has shown that well-made discharge shielding bags will protect even the most sensitive electronic parts through any expected shipping and storage situation. Specifications call for < 50 nJ interior energy or less from a 1 kV exterior discharge. Well-made bags allow < 10 nJ in the test procedure described in 7.4.

## 5 Types of material

### 5.1 Filled polymers

Many polymeric resins can be filled with a significant loading of conductive or dissipative materials that impart electrical properties to the base material. While it is somewhat difficult to control the loading to achieve a specific resistance level in the mid-dissipative range, low resistance levels are relatively easy to obtain with carbon black, metal flakes, nano-tubes, graphite fibres, etc. Filled polymers are used in vacuum forming, injection moulding and film extrusion.

### 5.2 Intrinsically conductive or dissipative

Additive elements are reacted with the polymer and become part of the molecular chain, generally at the ends of the molecules. The conductivity of the matrix is controlled by how many molecular ends come into contact. The polymer materials can be formulated in a wide range of electrical properties that are permanent and not readily affected by normal external and environmental influences.

### 5.3 Surface coated

Base polymers can be coated with conductive or dissipative materials to impart a level of electrical resistance to the exterior surface of a material. Coatings can be in the form of paint, resin or other curable liquid. Generally, the coating liquid will contain conductive filler similar to those used in filled polymers discussed in 5.1.

### 5.4 Antistat treated

Antistats are a chemical species that generally absorb moisture from the air. Antistats are coated on surfaces to provide some level of conductivity and surface lubricity. In contact and separation activities, some of the antistat material will transfer between surfaces to limit electrostatic charge separation. Antistat treated surfaces are not considered permanent and surfaces can require retreatment to retain low charge generation properties.

### 5.5 Anodized materials (e.g. boats used inside automated handlers, metal tubes)

Anodized surfaces are generally high in surface resistance but impart durable and hard coatings to aluminium to reduce wear and abrasion. Anodized materials are available at the high end of the dissipative electrical range but are relatively rare and are only available by special order. Many anodized surfaces are charge generators when in contact with production materials, so care is needed in process lines where these surfaces are used. While the base aluminium can be bonded to machine parts and ultimately earthed (grounded), the anodized surface can be insulating and therefore isolated from the bonding connection to earth. The anodized surface can then become a charge generator. Anodized surfaces can become damaged and may have pin-holes. These surfaces can also break down at moderate voltages. These limitations can lead to charged devices discharging through the anodization with high current. Anodization resistance can be highly voltage dependent and decay times lengthen as the voltage decreases. This could present a significant hazard for devices with low withstand CDM device protection.

### 5.6 Material processing

#### 5.6.1 Vacuum forming

Polymeric sheets are heated and placed over a form. A vacuum draws the heated sheet into the form and the sheet takes on the shape of the form. After cooling, the polymer is removed from the form and trimmed. Simple shapes can be made by vacuum forming although intricate surface patterns can be formed with many materials. Deep draws of filled polymers can result in significant changes in the electrical resistance of the finished product, especially at corners or edges. Complete loss of continuity across edges can occur so it is important to verify the resistance of the finished item across edges and corners using point-to-point resistance tests (see 7.3).

#### 5.6.2 Injection moulding

Three dimensional shapes are made by injecting a molten resin into a complex mould. Intricate shapes can be formed using injection moulding techniques and equipment. Care is needed in evaluating injection moulded parts formed from dissipative and conductive resins since the strain on the polymer compound often changes the electrical properties of the material, especially at corners. Complete loss of continuity across edges can occur so it is important to verify the resistance of the finished item across edges and corners using point-to-point resistance tests (see 7.3).

#### 5.6.3 Embossing

Embossing is a mechanical process that changes the surface topography of a material. Embossing can help reduce charge generation by reducing the surface contact area. Evaluation of the charging properties requires developing a technique as discussed in 7.2.

#### 5.6.4 Vacuum vapour deposition

Vacuum vapour deposition is used to form a metal layer on a polymer surface. The process is done under high vacuum so that the molten metal and subsequent vapour does not damage the base polymer.

#### 5.6.5 Surface coating

Surface coating is a technique used to apply materials to a flexible substrate. Many of these processes are done on a moving web in a roll-to-roll gravure process where a machine roller carries the coating material from a pan or trough and transfers the coating material to a polymer, paper or other flexible medium by contact. Curing takes place, often in an oven, prior to rolling up the finished web. This is a process used in many industries including printing and tape manufacture.

#### 5.6.6 Lamination

Lamination is used to combine two or more materials into a single structure. Lamination processes can make highly complex structures, normally in a planar or flat form. In some cases, laminated sheets can be used in vacuum forming operations but care should be used since bending can alter the functional properties of individual layers in the lamination and reduce the adhesion between layers.

## 6 Existing standards for packaging materials

### 6.1 IEC 61340-5-3

IEC 61340-5-3 provides an overview of typical packaging materials, packaging material applications, definitions of terms and material specifications. Test methods include surface and volume resistance for planar materials, two-point electrical resistance, and discharge shielding for bags.

The ability to measure electrical resistance on shapes other than flat surfaces or materials where the specified two-point probe will not fit are not covered by IEC 61340-5-3. Discharge shielding methods for materials or items beyond bags are not covered by IEC 61340-5-3.

### 6.2 ANSI/ESD S541

ANSI/ESD S541 provides an overview of typical packaging materials, packaging material applications, definitions of terms and material specifications. Test methods include surface and volume resistance for planar materials, two-point electrical resistance, and discharge shielding for bags.

The ability to measure electrical resistance on shapes other than flat surfaces or materials where the specified two-point probe will not fit are not covered by ANSI/ESD S541. Discharge shielding methods for materials or items beyond bags are not covered by ANSI/ESD S541.

### 6.3 Military standards and other documents related to packaging

#### 6.3.1 General

Military standards related to packaging materials contain specific information that is useful in preparing a packaging plan for electronic and other ESDS. USA military standards are part of the public domain and can be readily accessed for free reference (Assist – Quick Search Data Base – www.quicksearch.dla.mil).

#### 6.3.2 MIL PRF 81705 (E) (Film)

This is one of the most important standards in the packaging industry related to electronic products. It evolved over the years from the 1970's to the 1990's and contained specifications for three types of film material used to form bags. Type I is a metal foil barrier film used for moisture vapour barrier applications and moderate electromagnetic shielding; Type II was a low charging and dissipative transparent polymer material; and Type III is a transparent electrostatic discharge shielding material. The most recent version of MIL PRF 81705 (E) has dropped the Type II materials. The specifications for Type I and Type III films are well documented and have the backing of historical performance. If referencing MIL PRF 81705, be aware that resistance values are stated in terms of ohms square which are a factor of 10 higher than the surface resistance as defined in IEC 61340-5-3.

#### 6.3.3 MIL STD 3010

Test methods (replaces FTMS 101C). This document contains a number of test methods for physical and mechanical testing of packaging materials. The most often referenced procedure is Method 4046 – Static decay. Method 4046 uses a special apparatus to apply a potential to a sample of film held in a fixture. A minimum amount of conductivity is needed by the sample under test in order to accept the charging potential. After the material is charged, the sample is earthed (grounded) and the time for the potential to drop measured. Generally, the method is useful for a narrow range of samples with surface resistivity from $10^{10}$ Ω to $10^{13}$ Ω and applies only to homogeneous film samples. References to Method 4046 often appear in data sheets so care should be exercised in interpreting the claims made by suppliers.

#### 6.3.4 MIL PRF 131

Barrier materials, waterproof, greaseproof. This standard applies to many forms of packaging materials for shipping items to the military. References to electrical and electronic products defer to MIL PRF 81705 for electrostatic related specifications. MIL PRF 131 is mentioned here since it can apply to military contractors who supply to the US military.

## 7 Existing test methods for packaging materials

### 7.1 IEC 61340-2-1 – Ability of materials and products to dissipate static electric charge

IEC 61340-2-1 describes test methods for measuring the rate of dissipation of static charge of insulating and static dissipative materials and products. It includes a generic description of test methods and detailed test procedures for specific applications.

IEC 61340-2-1 describes the use of a corona charging and discharging apparatus, an electrostatic field meter and a charged plate apparatus. There are descriptions of how to make decay type measurements for textiles, gloves and finger cots, and tools. Several of the test procedures can be adapted to packaging materials but there are no specifications given to aid the end user in determining the relevance of decay measurements on packaging materials. Concepts and procedures need development.

### 7.2 IEC TR 61340-2-2 – Measurement of chargeability

IEC TR 61340-2-2 describes the equipment, arrangements and procedures for measurement of electrostatic charge caused by contact and relative motion between materials and presents examples of model experiments to simulate practical processes.

IEC TR 61340-2-2 describes the Faraday pail, field mill, field meters (several types), charged plate monitors (several types), non-contact electrostatic voltmeters and contact electrostatic voltmeters and gives guidance on their use to evaluate electrostatic charging situations. Generic descriptions of rubbing tests, sliding tests and film passing over rollers are described. Applications for packaging materials are not specifically mentioned but many of the techniques can be useful in the evaluation of packaging materials. Skilled practitioners are needed to interpret the results of chargeability tests.

### 7.3 IEC 61340-2-3 – Resistance and resistivity

IEC 61340-2-3 describes test methods for the determination of the electrical resistance and resistivity of solid materials in the range from $10^4$ Ω to $10^{12}$ Ω used to avoid electrostatic charge accumulation.

A concentric ring probe for surface and volume resistance measurement is described as is the probe used for point-to-point resistance and resistance to ground/groundable point measurements.

The concentric ring probe is used on planar solid materials with a minimum size of at least 80 mm x 120 mm or 110 mm diameter.

The full size (63,5 mm diameter) point-to-point electrodes are not normally used for packaging materials (application is normally for flooring, work surfaces, garments, etc.). However, if the sample or material under investigation is of a size greater than 415 mm x 165 mm, the probes could be used to provide some information about the point-to-point resistance of the material. This might be a useful technique for large containers (tote boxes) or wrapping materials.

Point-to-point probe is used as a test method to measure the resistance between two points on an item's surface. It is intended for measuring the resistance of items in the range of $10^4\ \Omega \leq R < 10^{12}\ \Omega$. The probe consists of 2-pogo pins, nominally 3 mm in diameter, held a fixed distance apart, nominally 3 mm. A consistent force is applied to the pogo pins during a measurement so that the contact force can be controlled. Most of the time, the metal ends of the pogo pins have a conductive rubber cover or insert to make a conformable contact surface.

### 7.4 IEC 61340-4-8 – Discharge shielding – Bags

IEC 61340-4-8 provides a test method for evaluating the performance of electrostatic discharge shielding bags. The design voltage for the test apparatus is 1 000 V.

The purpose of IEC 61340-4-8 is to ensure that material manufacturers, testing laboratories and end users who use this test method to evaluate a given packaging material will obtain similar results.

The test procedure uses a human body model (HBM) based discharge simulator to deliver a defined discharge pulse to a standard size bag. A capacitive probe is placed inside the bag so that the top and bottom metal plates of the probe are in contact with the inside surfaces of a bag under test. The plates of the capacitive probe are connected by a defined resistor and a suitable current probe is placed over the resistor wire on the output side. The current probe is attached to a suitable storage oscilloscope to capture and record the current pulse through the resistor after applying a 1 000 V HBM pulse to the top side of the bag. The area under the observed discharge current pulse is equal to energy in joules (watt-seconds). The method has been designed and used for bags, pouches and similar packaging materials since the late 1970's so there is a great amount of history. Most of the packaging material suppliers that provide electrostatic discharge shielding bags will report their product test results and define their product specifications using this test method.

## 8 Choosing a packaging technology

### 8.1 Determining packaging material attributes

Determining packaging material attributes to meet application requirements: The first step in deciding what a packaging material needs to do is have an understanding of the logistics that the shipped material will experience. Fundamentally, a determination of how the packaged items will be handled should be made first. If the packaged item (product) is only handled inside of an electrostatic protected area (EPA), requirements for packaging materials might be reduced. If the product is shipped and moved through unknown or to unprotected areas, that increases requirements for electrostatic and other protection.

### 8.2 Inside an EPA

The first consideration inside an EPA is that electrostatic protective packaging might not be required at all. If packaging or some form of container is needed to hold items, the packaging material should be low charging and dissipative or conductive. Conventional insulating materials should be excluded from the EPA. Any process essential insulating materials in the EPA have certain requirements that should be met in order to continue to claim compliance with the ESD control program plan. Low charging and dissipative/conductive materials can be used for carriers, tote boxes, trays, tubes and other forms of carriers for ESDS.

### 8.3 Outside an EPA or between EPAs

The considerations change when ESDS have to be moved outside an EPA, between EPAs through unprotected areas, or from an EPA to an unknown receiving environment. Low charging and dissipative properties are required for intimate contact with ESDS. It is important to reduce the charging propensity of the ESDS. In addition to the intimate contact material, the ESDS should be shielded to reduce the influence of external electric fields. Shielding in this case can take the form of an air gap for separation of the ESDS from the outside environment, or direct shielding using a highly conductive enclosure such as a discharge shielding bag or conductive container.

### 8.4 Evaluation of packaging system attributes

As discussed in this document, the properties related to electrostatic protection of ESDS are basically as follows: charge generation, charge dissipation and shielding. While test methods exist for each of the properties, some packaging forms (see Annex A for an overview of packaging forms and types) do not readily lend themselves to the direct measurements so indirect measurements are needed. Indirect measurements include several forms of electric resistance testing. Industry experience has shown that for a large range of resistance, the measured resistance value can relate very well to charge dissipation rates.

### 8.5 Charge dissipation test methods

Charge dissipation test methods exist but are generally limited to those materials with high surface or volume resistance. Most often, the dissipation rate of materials within what is considered electrostatic dissipative, that is $< 1 \times 10^{11}\ \Omega$, is faster than can be reasonably measured by the conventional timers used in charge dissipation testers. Decay time is a function of capacitance and resistance so therefore resistance can be used to approximate decay time for materials with surface or volume resistance $< 1 \times 10^{11}\ \Omega$.

### 8.6 Resistance measurement methods

Resistance measurement methods are often used to measure and define materials and finished goods, particularly in packaging. The following Table 1 defines the generally accepted resistance limits assigned to packaging materials. The table is similar to Table 1 of IEC 61340-5-3:2015.

**Table 1 – Test methods for electrostatic protective packaging**

| Material classification | Test method [c] | Method description | Limits |
|---|---|---|---|
| Conductive | IEC 61340-2-3<br>ANSI/ESD STM 11.13[a] | $R_s$; Surface resistance<br>$R_v$; Volume resistance<br>$R_{p-p}$; Point-to-point resistance | < 1 × $10^4$ Ω |
| Electrostatic field shielding | IEC 61340-2-3 [b] | $R_s$; Surface resistance<br>$R_v$; Volume resistance | < 1 × $10^3$ Ω |
| Dissipative | IEC 61340-2-3<br>ANSI/ESD STM 11.13 [a] | $R_s$; Surface resistance<br>$R_v$; Volume resistance<br>$R_{p-p}$; Point-to-point resistance | ≥ 1 ×1 $0^4$ Ω to < 1 × $10^{11}$ Ω |
| Insulative | IEC 61340-2-3<br>ANSI/ESD STM 11.13 [a] | $R_s$; Surface resistance<br>$R_v$; Volume resistance<br>$R_{p-p}$; Point-to-point resistance | ≥ 1 × $10^{11}$ Ω |

[a] IEC 61340-2-3 describes all three test methods $R_s$, $R_v$ and $R_{p-p}$.

[b] IEC 61340-2-3 describes test methods for the determination of the electrical resistance and resistivity of solid materials in the range from $10^4$ Ω to $10^{12}$ Ω. When using the concentric ring probe according to IEC 61340-2-3 for surface and volume resistance, the probe can be used to measure values less than $10^3$ Ω. The test voltage can be lowered in this case.

[c] For product qualification of packaging materials, the environmental conditions for preconditioning and testing should be 23 °C ± 2 °C and 12 % ± 3% relative humidity. The preconditioning before the measurement should be ≥ 48 h.



### 8.7 Shielding test

A shielding test for bags and pouches is described in IEC 61340-4-8. In this procedure, a human body model (HBM) simulator is used to apply a 1 000 V discharge pulse to a bag or pouch under test.

## 9 Does the packaging system meet the intended purpose?

Of importance is the need to ensure that the packaging system that has been selected will meet the intended purpose. This will include an evaluation of the protection ability of the packaging system to make sure it can meet the demands of the shipping or storage conditions. Tests can include vibration, heat and cold, moisture barrier protection and any other physical attribute that are beyond the scope of this document, but nonetheless should be considered.

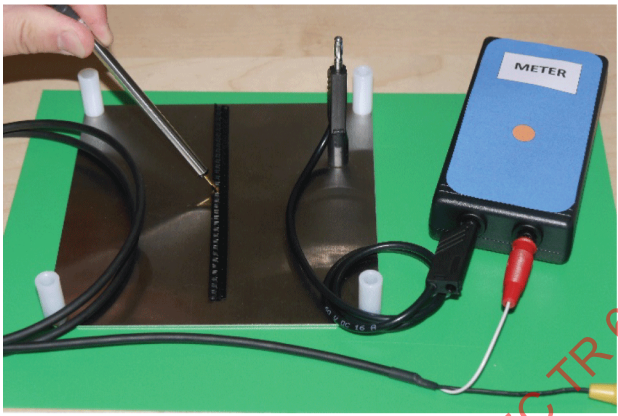
## 10 New test method concepts and development plans

### 10.1 General

As has been pointed out, the existing test methods cannot be used as intended on all packaging forms. Some of the packaging forms are too small or of an odd shape that will not allow application of test probes or electrodes. It should be noted that controlling or defining electrical resistance alone cannot solve all static electricity problems. More work is needed to develop appropriate evaluation techniques and test method for small profile embossed (pocket) tape and other packaging materials used for small electrical and electronic parts.

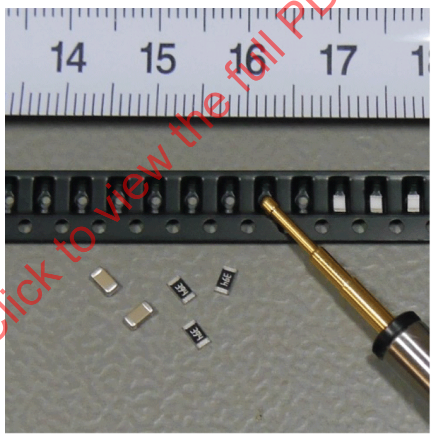
### 10.2 Single point probe

A single point test method is being considered by the ESD Association in the USA. The design of the probe is based on the description of the point-to-point probe in IEC 61340-2-3. The contacting probe is one of the pogo-pin type contacts used in the same point-to-point probe discussed in 7.3. The counter electrode will be another portion of the item under test or a conductive counter electrode that the item under test will rest upon (see Figure 5 and Figure 6).




IEC

**Figure 5 – Single point probe test method set-up**



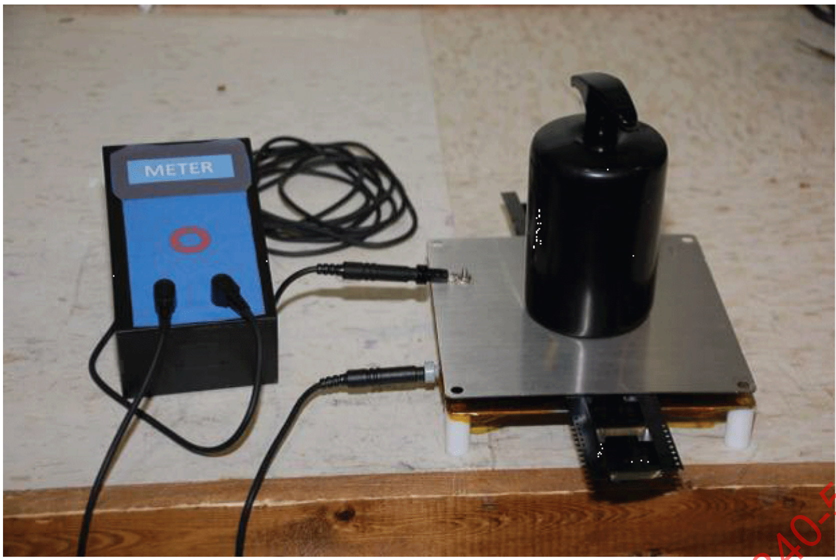

IEC

**Figure 6 – Single point probe on embossed (pocket) tape**



### 10.3 Parallel plates

A concept of placing an item under test such as a strip of embossed (pocket) tape on a metal plate that acts as one measurement electrode and another metal plate on top of the item under test that acts as the other measurement electrode was discussed in an EOS/ESD Symposium paper in 2012 (see Figure 7). The test method will eventually undergo further evaluation in a new project within the ESD Association Packaging working group 11.




IEC

**Figure 7 – Parallel plate test method set-up**

### 10.4 Pin-point probe

Normal pin-point probes as used with an ohmmeter can have some application for measuring small featured packaging material where a two-point or single point probe described above will not fit the surface being measured. Care is needed in the interpretation of results since the material loading may not be uniform and the results could be sporadic.

### 10.5 Shielding related test methods

Shielding tests for packaging beyond bags has not been developed. Testing with actual electronic components that can be evaluated for parametric changes can be the best way to evaluate packaging beyond bags. Place a component in the package of interest and discharge known levels of electrostatic discharge to the exterior of the package. Remove the component and test for changes. Elevate the discharge potential/current to the point of failure. This will give the user some level of confidence in the ability of the package to provide protection from external discharge events. Alternatively, conductive and dissipative materials in combination with a barrier, spacing or air gap as described in IEC 61340-5-3 may provide shielding for component protection.

### 10.6 Charge generation – Triboelectrification test methods

Reel to reel test fixtures can be built to allow carrier tape (embossed pocket tape) and cover tape measurements as shown in Figure 8. Care is needed to make sure the tape reels are isolated from each other and from ground so that the carrier tape or cover tape provides the only physical connection between the reels. Charge can be applied from a power supply to the conductive reel on one side and the discharge to ground monitored from the other reel as shown in Figure 10. The same apparatus can be used in measuring resistance between reels (Figure 9).

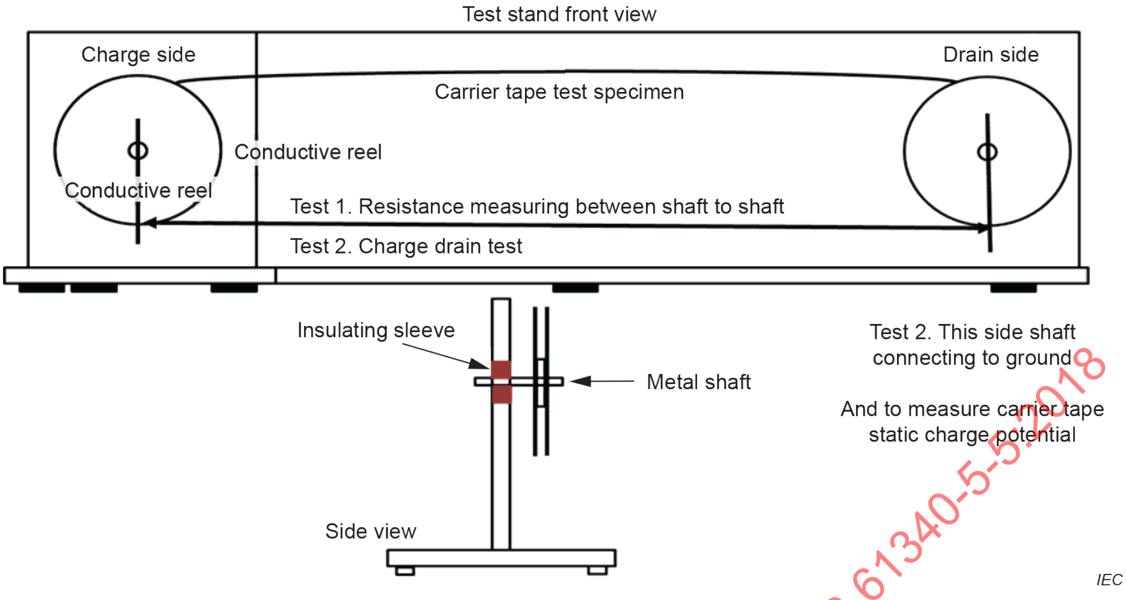



**Figure 8 – Set-up of isolated tape reels**

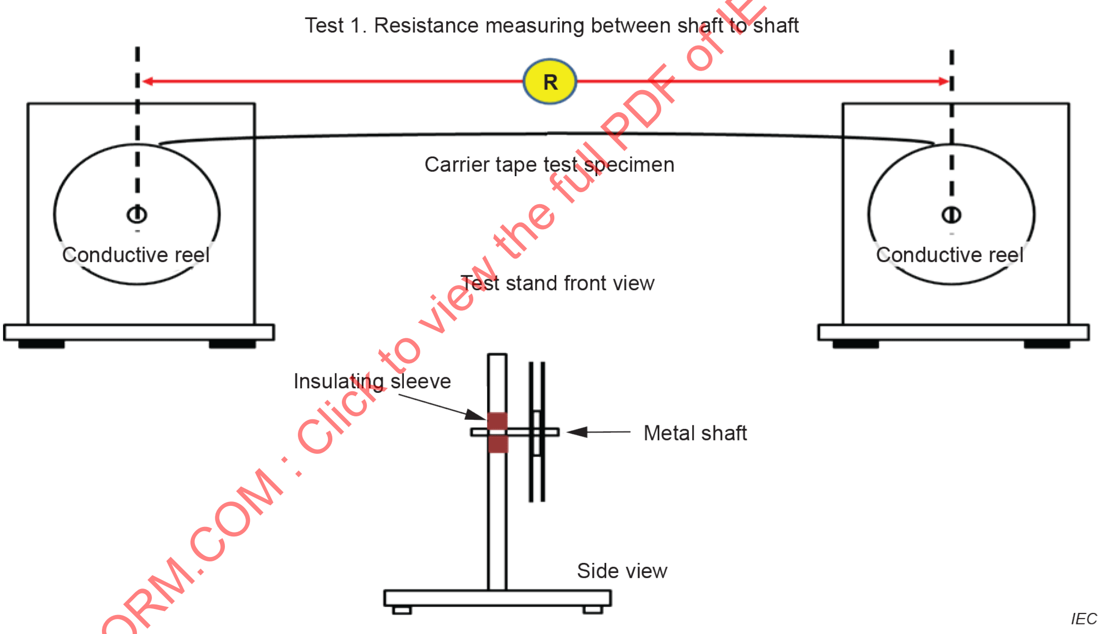



**Figure 9 – Resistance measurements – Reel to reel**

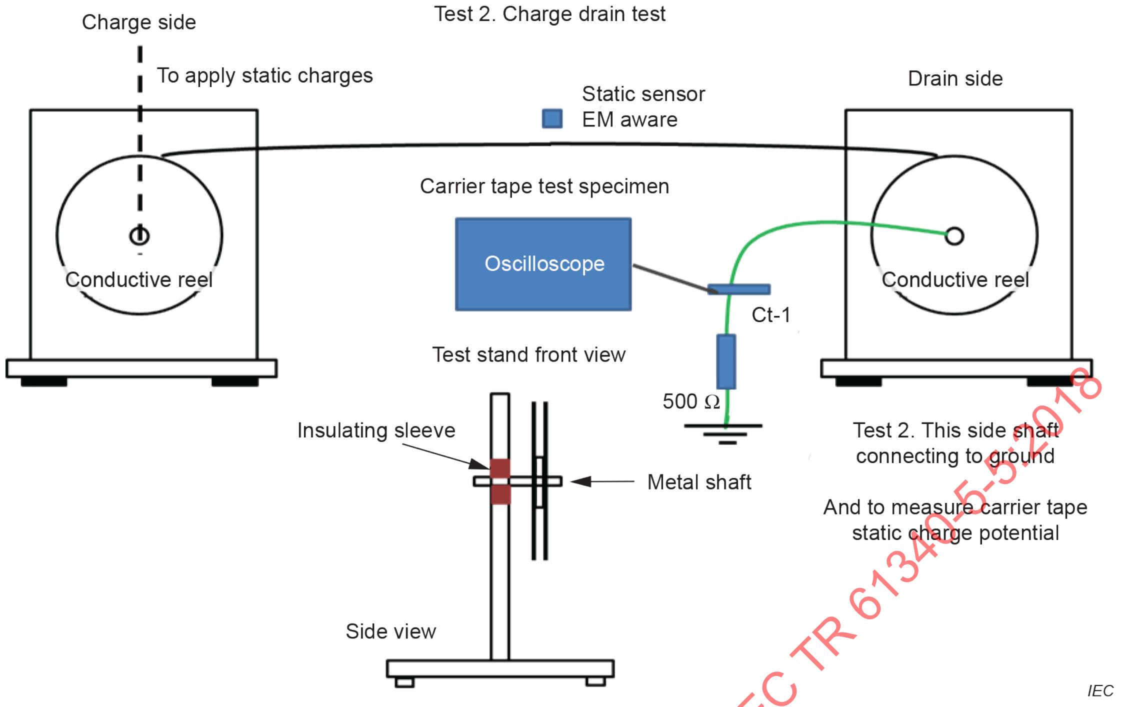



**Figure 10 – Charge drain test – Reel to reel**

## 10.7 Triboelectric charging of cover tape

Triboelectric charging of cover tape removal can be measured as shown generally in Figure 11. The test uses a charged plate monitor (CPM). A substrate material or carrier tape is mounted to the CPM. The cover tape is removed from the sample (several samples need to be prepared in advance) at various peeling rates. The rate of cover tape removal should simulate the speed of removal in an actual pick-and-place application. The resulting voltage can be captured using various data recording methods depending on the CPM output.

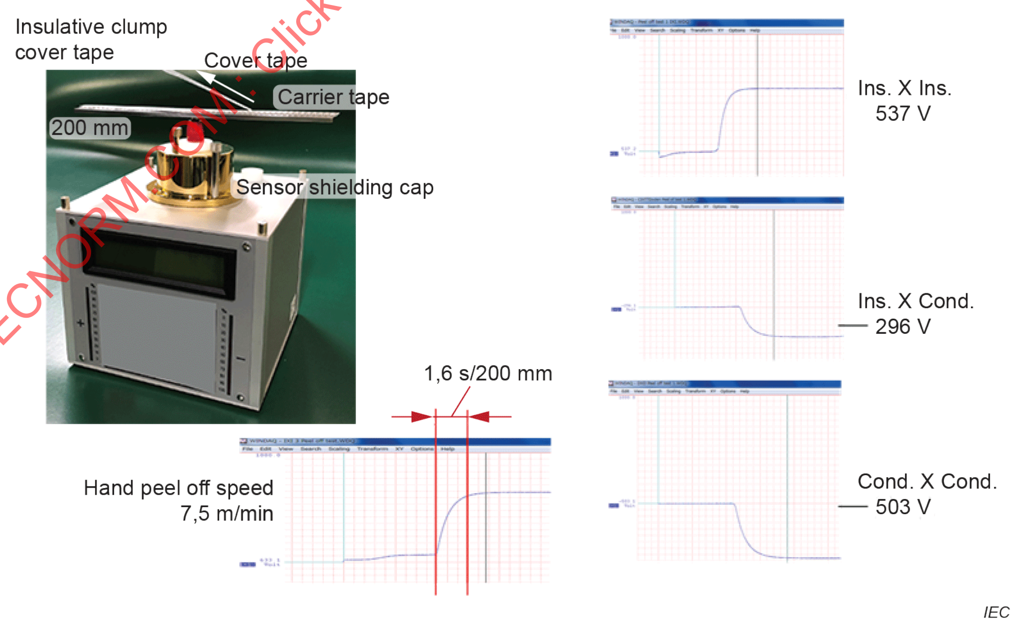
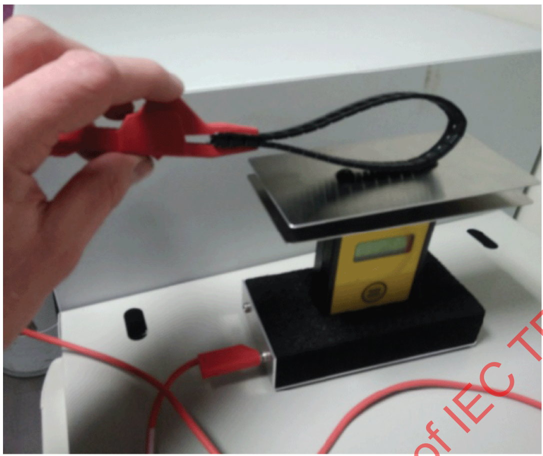



**Figure 11 – Cover tape evaluation concepts**

### 10.8 Discharge evaluation method

An electrostatic field meter with charged plate and charging source (used for evaluating air ionizers), can be used to provide an indication of packaging material discharging ability (see Figure 12). One side of the packaging material under test is bonded to the electrostatic field meter ground, the other side is placed into contact with the charged plate (charged to > 1 kV). The time for the charge to dissipate through the packaging material gives a good indication for the material classification. This procedure is similar to the test method described in IEC 61340-2-1.



IEC

**Figure 12 – Discharge evaluation method**

### 10.9 Other resistance test methods

Several test method documents for measuring the electrical resistance of surfaces utilize parallel bars of conductive material separated by fixed dimensions placed on a surface. The current flow between the parallel bars is measured to obtain the electrical resistance. The parallel bars may be of metal, conductive elastomers, or conductive paint placed on the surface. IEC 60079-32-2 describes several of the electrode types. All have the same geometry of 100 mm parallel bars, each ≥ 1 mm in width, separated by 10 mm. The electrode configuration generally provides similar results in ohms as the standard concentric ring electrode. Using the parallel bar electrode may provide more accurate results than other resistance measuring electrodes when the tested material has uneven or a very hard surface.

When possible, it is best to compare the results obtained using various electrodes on a surface under test to observe how the surface reacts to the different ways that current is applied to make the measurement.

# Annex A
(informative)

# Packaging forms and types

## A.1 Packaging materials for electronic devices

Annex A contains general information about a variety of packaging forms used with electronic parts and is limited to the following packaging forms: tape and reel, formed trays, tote boxes and other rigid containers. It is expected that other general packaging forms can be evaluated using existing techniques or those that will be developed as a result of this document.

## A.2 Embossed tape

Embossed (pocket) tape and cover tape are available in a wide variety of materials and nearly infinite profiles. Very sensitive components are usually packaged in conductive embossed tape with some form of dissipative/conductive/shielding cover tape. Some sizes can be evaluated with existing resistance measurement methods such as described in 7.3. Small profile embossed tape made from conductive materials cannot be adequately evaluated with the existing test methods since the probes are too large. More work is needed to develop test methods for small profile embossed tape (see Clause 10). Examples of various small profile embossed (pocket) tapes are shown in Figure A.1 alongside rulers marked in millimetres to indicate scale.

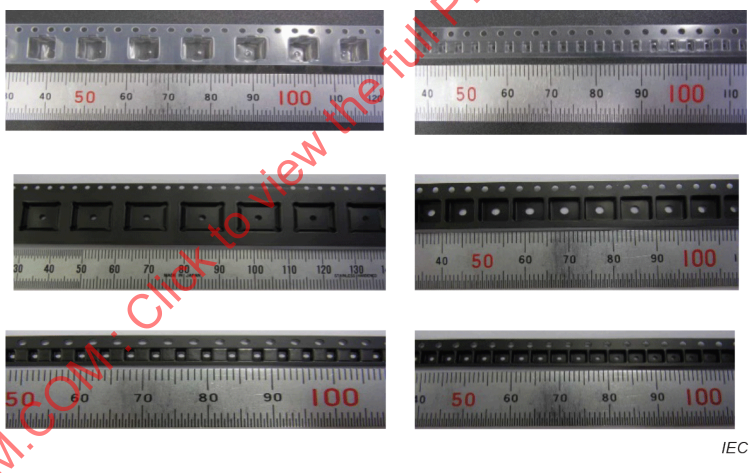



**Figure A.1 – Examples of embossed (pocket) tape**

## A.3 Cover tape

Cover tape is used to enclose parts within an embossed tape. There are fewer material options for the cover tape than the embossed tape. There are also some differences in material properties available from the different producers of cover tape. It is well known that some cover tapes can generate enough electrostatic charge when removed to attract small profile parts to the cover tape. This can cause significant production issues. The small part attraction can occur beginning at electrostatic field strength on the order of 1 000 V at 2,5 cm with the small capacitors and resistors commonly used in circuit board manufacturing today. Fortunately, cover tapes, even the narrowest versions, can be measured with existing test methods for electrical resistance. Charge generation tests can also be adapted from existing methods. Of most importance is the measurement of charge or electric fields from the cover tape when removed from the embossed tape (Figure 11). If the cover tape or the contacting adhesives to the conductive embossed tape are conductive or dissipative and the cover tape