

SEMI E163-0212 (Reapproved 1217) GUIDE FOR THE HANDLING OF RETICLES AND OTHER EXTREMELY ELECTROSTATIC SENSITIVE (EES) ITEMS WITHIN SPECIALLY DESIGNATED AREAS

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1 Purpose

1.1 The purpose of this Document is to minimize the negative impact on productivity caused by static charge and electric fields in semiconductor manufacturing equipment and facilities. It is a Guide for establishing optimum electrostatic compatibility of the handling environment for reticles and other items that are extremely electrostatic sensitive (EES) to electrostatic charge, voltage, and electric field. This Guide is complementary to SEMI E78 and SEMI E129 and is intended to improve the protection of the most electrostatic damage-susceptible items.

NOTE 1: For the purposes of this Document, EES items are those that are affected by any combination of electrostatic charge, electrostatic voltage, or electric field.

1.2 This Document can be used as a Guide for equipment manufacturers during the design and testing of their equipment and by those who either use or produce reticles and other EES items.

1.3 Process technology used in the manufacture of semiconductors and electronic devices continues to achieve increases in active feature density and device complexity. With increased levels of integration, longer interconnects, and smaller conductor separations, sensitivity to field-related problems increases. This Document provides recommendations for addressing the problem of damage through closer examination of electric field as a supplement to existing static charge mitigation techniques.

2 Scope

2.1 The scope of this Document is limited to the definition of principles for handling reticles and other EES items within a specially designated controlled environment and recommendation of an appropriate level of electric field to maintain within that environment.

2.1.1 This Document presents recommendations about grounding and material selection that conflict with established methods of electrostatic charge control (e.g., those defined in ANSI/ESD S20.20 for devices of 100 volt human body model [HBM] sensitivity) so the guidance given here should be applied only within a specially designated and clearly identified area.

2.2 This Document references SEMI E78, SEMI E129, SEMI E43, and other methods of measuring electrostatic parameters. The set of Documents is complementary, providing guidance on managing different aspects of electrostatic risk under a wide range of conditions.

2.3 While this Document makes frequent reference to electrostatic fields and effects, for the purposes of this Guide this should also be considered to include alternating, variable, and transient electric and electromagnetic fields. All such fields can potentially generate electrical stress within an EES item.

2.4 Wherever this Document makes reference to reticles, this should be regarded as an example of an EES item that has been studied in depth and which is being used for illustrative purposes. The principles being discussed may also be relevant to other items that exhibit extreme electrostatic sensitivity so the guidance should not be regarded as exclusive to reticles and reticle handling. Such EES items may include small geometry device structures on wafers, packaged devices in back end processing where charged device model (CDM) sensitivity may be a problem, and device structures on glass in flat panel display (FPD) manufacturing.

NOTICE: SEMI Standards and Safety Guidelines do not purport to address all safety issues associated with their use. It is the responsibility of the users of the Documents to establish appropriate safety and health practices, and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 *General* — This Guide contains general recommendations.

3.1.1 Specific field-related problems or certain devices may require or allow different levels of electric field than are recommended in this Document.

3.1.2 The calculation of electric field induction involves some simplification, but the effects of such simplification will be within the typical measurement accuracy of accepted field measurement techniques.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI E43 — Guide for Electrostatic Measurements on Objects and Surfaces

SEMI E78 — Guide to Assess and Control Electrostatic Discharge (ESD) and Electrostatic Attraction (ESA) for Equipment

SEMI E129 — Guide to Assess and Control Electrostatic Charge in a Semiconductor Manufacturing Facility

4.2 *ESD Association Standards and Advisories*¹

ANSI/ESD STM3.1 — ESD Association Standard Test Method for the Protection of Electrostatic Discharge Susceptible Items – Ionization

ANSI/ESD SP3.3 — ESD Association Standard Practice for the Protection of Electrostatic Discharge Susceptible Items – Periodic Verification of Air Ionizers

ANSI/ESD S20.20 — ESD Association Standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

ESD TR3.0-02-05 — ESD Association Technical Report – Selection and Acceptance of Air Ionizers

4.3 *Other Documents*

ITRS — International Technology Roadmap for Semiconductors²

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AFM* — atomic force microscope

5.1.2 *ANSI* — American National Standards Institute

5.1.3 *CDM* — charged device model

5.1.4 *CD* — critical dimension

5.1.5 *EES* — extremely electrostatic sensitive

5.1.6 *EFM* — electric field-induced migration

5.1.7 *EMI* — electromagnetic interference

5.1.8 *ESA* — electrostatic attraction

5.1.9 *ESD* — electrostatic discharge

5.1.10 *ESDS* — electrostatic discharge sensitive

¹ Electrostatic Discharge Association, 7900 Turin Road, Building 3, Rome, NY 13440-2069, USA; Telephone: +1.315.339.6937, Fax: +1.315.339.6793, <http://www.esda.org>

² ITRS Global Communication Center, SEMATECH, 2706 Montopolis Drive, Austin, TX 78741, USA; <http://public.itrs.net>

5.1.11 *FPD* — flat panel display

5.1.12 *IC* — integrated circuit

5.1.13 *ITRS* — International Technology Roadmap for Semiconductors

5.1.14 *MR* — magneto-resistive

5.1.15 *SMIF* — standard mechanical interface

5.2 Definitions

5.2.1 *carrier* — a device for holding wafers, dies, packaged integrated circuits (ICs), or reticles for various processing steps in semiconductor manufacturing. [SEMI E78]

5.2.2 *extremely electrostatic sensitive (EES) item* — any item that is very highly susceptible to degradation or malfunction caused by electrostatic charge, voltage or field, even when handled under conditions that would normally be classified as ‘electrostatic discharge (ESD) controlled’.

5.2.3 *extremely electrostatic sensitive (EES) minienvironment carrier* — a transport method for extremely electrostatic sensitive (EES) items that excludes electric fields by surrounding the EES item with a Faraday cage (i.e., a conductive enclosure).

5.2.4 *electromagnetic interference (EMI)* — any electrical signal in the nonionizing portion of the electromagnetic spectrum with the potential to cause an undesired response in electronic equipment. [SEMI E33]

5.2.5 *electrostatic compatibility* — charge control adequate to allow the manufacturing of products and the inter-equipment transfer of products, reticles, and carriers without electrostatic problems. [SEMI E129]

5.2.6 *electric field-induced migration (EFM)* — the movement of normally stationary atoms or molecules on a surface as a consequence of the presence of an electric field.

NOTE 2: Related Information 1 describes the characteristics of EFM in chrome-on-glass reticles.

5.2.7 *electrostatic discharge (ESD)* — the rapid spontaneous transfer of static charge induced by a high electrostatic field. [SEMI E78]

5.2.8 *minienvironment* — a localized environment created to isolate product from contamination and people. [SEMI E78]

5.2.9 *product* — any item intended to become a functional semiconductor device. [SEMI E78]

5.3 Symbols

5.3.1 *C* — capacitance

5.3.2 *Q* — charge

5.3.3 *V* — voltage

6 Considerations About Assessing the Risk from Electric Field

NOTE 3: Appendix 1 of this Document contains a detailed treatment of the interaction between an electric field and a field-sensitive object (in this example, a reticle).

NOTE 4: Related Information 1 describes the methods that were used for determining the recommended electric field level for reticles. A similar approach may be adopted to determine the field sensitivity of other EES items.

6.1 Electric fields cause a number of undesirable effects in electronic device manufacturing environments.

6.1.1 Field induction can affect EES items such as reticles or FPDs without any physical contact between the source of the electric field and the sensitive item.

6.1.2 Field induction can cause damage within such EES items without any transfer of static charge to or from them.

6.1.3 Electric fields that do not cause ESD may still be a hazard to small device structures.

6.1.4 In some circumstances, the damage caused by exposure to electric fields can develop continuously over an extended period of time, resulting in gradual deterioration and eventual failure of the affected item.

6.2 Measurements of parameters such as electric field are difficult to make.

6.2.1 The nature of an object (i.e., insulator, conductor, or in most cases a mixture of both), its geometry, its surroundings, and the measuring equipment itself are only a few of the factors affecting the accuracy of an electric field measurement.

6.2.2 The levels of electric field that can cause progressive damage in EES items such as reticles may be lower than it is practical to measure with hand-held apparatus.

6.2.3 It is not possible to measure the internal electric field within an item such as a reticle or a packaged device. This internal field may be the result of static charge generated on its surface or fields through which it may pass when it is moving through equipment. However, sensor devices that can be handled in the same manner as the item of interest and that can record the electric field exposure that the item might experience are becoming available.

6.2.4 A field measurement made at a particular location and time may not be representative of the field that may be present in the same location at another time, or in another apparently identical location.

6.2.5 Electric fields may be transient in nature and may leave no permanent evidence that they have been present.

6.2.6 Not all field measurement equipment is sensitive to rapidly changing or transient fields.

6.3 It is difficult to relate the measurement of an electrostatic quantity like electric field to the effect it may have on a sensitive item.

6.3.1 Tests conducted with one sensitive item may not be representative of the effects that may be produced in another apparently similar item.

6.3.2 Almost every reticle in use has a unique conductor pattern and variations in the pattern of conductors and insulating spaces alter the field induction that will take place upon exposure to an electric field.

6.4 Due to the variable nature of reticle designs and the inability to quantify the field induction that takes place at different places in a reticle, it is not possible to establish definitive damage thresholds for production reticles. Therefore, guidance values for electric field exposure have been determined following experimentation with specially designed test reticles.

NOTE 5: Refer to Related Information 1 for details of the methods used and technical references.

6.5 It may be impossible to define electric field levels that ‘guarantee’ field-related problems are totally eliminated.

6.5.1 Due to the progressive deterioration of a reticle that can be caused by electric fields and the possibility of similar continuous damage effects in other field-sensitive items, no particular value of electric field can be considered as ‘safe.’ A weak electric field that is present for a long period may possibly cause more significant damage than a strong electric field that is present for a shorter time.

6.6 Damage may be caused by ‘internal’ or ‘external’ electric fields.

6.6.1 ‘Internal electric fields’ can be caused by an electrically isolated part of an object becoming charged electrostatically while another part remains uncharged. The epoxy encapsulation of a packaged device may be tribocharged during handling and this can create an electric field that emanates from the device.

6.6.1.1 If the leads of such a charged device are now connected to ground, a balancing charge attracted by the charge on the epoxy encapsulation will flow onto the leads. Externally, the object may appear to have been neutralized by connection to ground, but internal charge separation and hence an internal electric field will still exist.

6.6.1.2 The strength of the internal electric field and hence the risk of field-induced damage will have been ‘increased’ by grounding, even though the device may now appear to be electrically neutral and hence safe.

6.6.2 ‘External electric fields’ that can penetrate a field-sensitive object may be generated in many ways, but an electric field interacts with a field-sensitive object in exactly the same way regardless of its source.

6.6.2.1 An electric field coming from static charge on an insulating surface is equivalent to the same strength of electric field originating from a conductor connected to a power supply, in terms of the damage it can induce.

6.6.2.2 However, all sources of electric field are not equivalent in terms of how they can be treated.

6.6.2.2.1 Electric fields from static charges present on insulating surfaces or isolated conductive objects can be eliminated by using air ionization, but fields emanating from powered sources cannot be eliminated in this way.

6.6.2.2.2 Fields from powered sources can only be eliminated by shielding them with a grounded conductive enclosure (i.e., Faraday cage). The ability of a Faraday cage to shield alternating or rapidly varying fields depends on both the conductivity and continuity of the material used for its construction and the rate of change of the field. A metal Faraday cage protects against field penetration from any source.

6.6.3 'Field perturbation' will occur whenever conductors are introduced into an electric field. Such field perturbation can result in a greater electric field strength being present within a field-sensitive object, without there being any change in the charge state or voltage of the field source.

6.6.3.1 A field sensitive object is itself likely to perturb an externally produced electric field and may cause the local field strength to increase too much higher levels than might be measured in the absence of the object.

6.6.3.2 Similarly, the field strength within a field-sensitive object can be increased by changing its position relative to other conductive surfaces such as equipment panels, robot arms, and workbenches.

6.6.3.3 Such field perturbations may not be intuitively obvious. For example, the placement of a conductive ring around a planar array of isolated conductors (as in the case of a chrome border around the pattern area of a reticle) can cause the direction of the electric field between the isolated structures to reverse. The movement of any similar conductive structure (such as a ring-shaped carrier frame) close to a field-sensitive item could cause significant field perturbation and consequential damage.

6.7 Field induction is virtually instantaneous. It can take only picoseconds for an electric field to induce damage in a field-sensitive object such as a reticle, so even transient electric fields and perturbations caused by the movement of tools and equipment during material handling can be sufficient to cause damage. Such transient fields may not be detectable unless specialized high-bandwidth monitoring equipment is used.

7 Considerations for Assessing the Risk from Electrostatic Discharge (ESD)

7.1 When an ESD event happens during the handling of a charged, packaged device, there may be a very rapid transfer of a balancing charge onto the device leads. There may be no neutralization of the original charge on the device package material. When a charged object is connected to ground, even through a dissipative connection, the charge transfer that takes place delivers a balancing charge onto the device, not a neutralizing charge. This is illustrated in Figure 1.

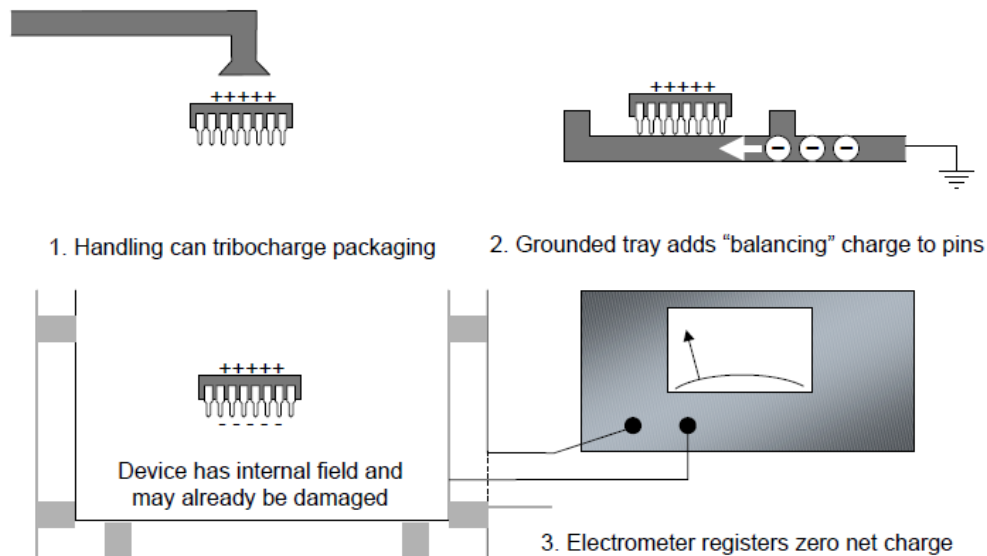


Figure 1
Charging During Packaged Device Handling

7.2 Since it is virtually impossible to eliminate the in-process charging of devices that takes place inside tools or equipment, measures should be taken to protect the devices even in the charged condition.

7.3 It is also important to recognize that measures that have been put in place to reduce the generation of ESD events in general—often to quite justifiably avoid equipment lock-ups and particle attraction—can actually increase the risk of damage to a sensitive device.

7.4 This Document explains that ESD avoidance and sensitive device protection do not always require the same methods and that grounding is not always the preferred method.

7.4.1 If a charged EES item is connected to ground through a dissipative contact, there may not be a damaging discharge at the moment of grounding as a controlled, balancing charge flows slowly onto the device pins. In normal ESD-prevention terms, there is no ESD event on contact. However, the gradual transfer of a balancing charge to the circuitry can raise the potential difference across an internal circuit junction to the critical point, causing internal damage. This happens as a direct consequence of connecting the pins to ground and allowing static charge elsewhere on the device to attract a balancing charge into the circuitry. The device can now appear to be macroscopically neutralized. There will have been no ESD event at the moment of grounding and no event registered on any ESD sensors used to monitor the production area, but the device may have been damaged internally.

8 Apparatus

8.1 *Electrostatic Charge Measurement* — For measuring the charge generated on product, reticles, or carriers as defined in SEMI E78, the Faraday cup test method is shown in Figure 2 and is described in more detail in SEMI E43. However, when using this method to measure charge on EES items, inaccurate results may be obtained due to the presence of balanced charges that produce internal electric fields as described previously (refer to § 6.6.1).

8.1.1 Insulators and complex EES items are capable of simultaneously being charged with both polarities of static charge. Measurement with a Faraday cup will indicate the net excess charge on an object, not the amount of ‘charge separation’ within it.

8.1.2 If a tribocharged item being tested has been grounded at any time during its movement into the Faraday cup, for example by the use of an equipotential bonding scheme for ESD management, a balancing charge may have been placed on it that will nullify the charge measurement.

8.1.3 An electrostatic fieldmeter or voltmeter may be capable of indicating whether this condition exists, but this may not always be possible.

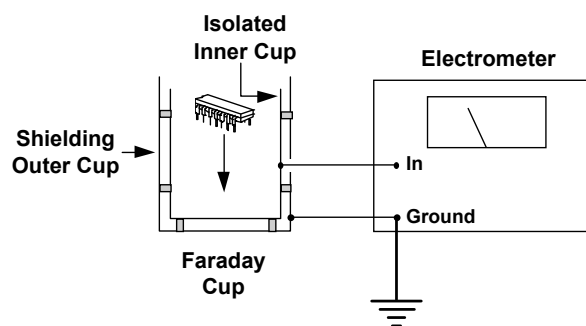


Figure 2
Faraday Cup Charge Measurement

8.2 *Electric Field Measurement* — The instrument used for making electrostatic field measurements is known as an electrostatic fieldmeter. Instructions concerning its use should be obtained from the instrument manufacturer and SEMI E43. Typically, an electrostatic fieldmeter measures at a distance of 2.54 cm (1 in.).

8.2.1 The measurement configuration shown in Figure 3 illustrates the effect of the instrument on the measurement. In most cases the presence of the fieldmeter will increase both the flux from the charged surface and the convergence

of the electric field lines. The fieldmeter will generally indicate a higher value of electric field than would be present without the fieldmeter.

8.2.2 An electrostatic voltmeter can be used as an alternative to the fieldmeter measurement. For small objects or surface areas, an electrostatic voltmeter is appropriate. Refer to SEMI E43 for further information.

8.2.3 Under appropriate conditions, electrostatic voltmeters exhibit a high degree of accuracy and stability that is independent of the distance from the charged object. The electrostatic voltmeter probe can be located very close to a charged surface without arc-over, and it is able to resolve the field from a small charged object.

8.2.4 For measuring transient electric fields a high bandwidth electrostatic voltmeter with an output to a computer or a storage oscilloscope may be needed.

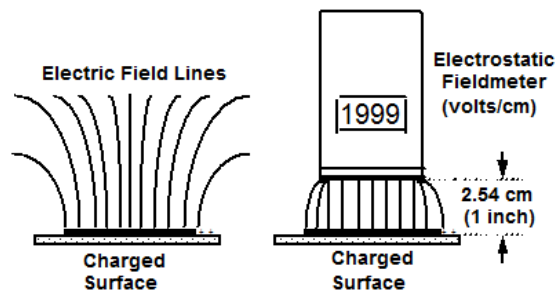


Figure 3
Electrostatic Field Measurement

8.2.5 For recording the electric field within the restricted handling environment of equipment, carriers, and process chambers where there is insufficient access for hand-held devices or where the presence of the probe itself would significantly alter the measurement, customized sensor devices may be required that can take the place of the EES item under consideration.

8.2.5.1 The electric field configuration in the presence of such a sensor device should be as close as possible to the field configuration with the EES item present. Such a device can sample virtually all the environments through which the EES item may pass and can record process- or handling-induced charging. It can also record the field exposure duration as well as the field strength. Therefore, this may be the most suitable way of assessing electric field risk for EES items.

9 Identification of EES Classified Zones

9.1 Owing to the different principles employed for EES item handling and the conflict with conventional ESD precautionary handling methods that use equipotential bonding (i.e., grounding) schemes, it is recommended that zones where EES items are handled be segregated and clearly marked.

9.1.1 The recommended symbol for identification of an EES item, handling zone, or equipment that is compatible with EES handling techniques is shown in Figure 4.



Figure 4
Recommended Symbol for Identifying an EES Item, Compatible Handling Zone, or Equipment

10 Principles for EES Classified Zones

10.1 The primary objective is to maintain an EES item in the absence of any static charge or electric field. There are two different aspects of protection for EES items—charge management and field management.

10.2 *Charge Management*

10.2.1 The safety of charge management by grounding, even through a resistive contact, will depend on the nature of the circuitry within the sensitive item, how rapidly excess charge flows to ground, and the route it takes. Grounding may also cause internal electric fields to increase as described previously. For these reasons, grounding of the EES item may need to be avoided, when possible, within an EES classified handling zone.

10.2.2 Within the EES zone, other methods of charge management, such as air ionization, are employed as an alternative to grounding. When charge cannot be safely neutralized, changes to handling methods may be needed to assure that charge generation does not occur. Materials that contact EES items may need to be selected to minimize triboelectric charge generation.

10.2.3 Air ionization is inherently capable of neutralizing charge at a rate that is unlikely to cause damage, so it can be used in place of grounding.

10.2.3.1 In any application of air ionization, it is necessary to assure that the ionized air reaches the charged surface. Air ionization operates relatively slowly, and sufficient time should be allowed for the ionization system to work.

10.2.3.2 Air ion streams respond to the presence of static charge by reacting to the electric field that is produced by the charge, so it is important to recognize that ionizers do not actually ‘prevent’ the generation of static charge or electric field.

10.2.3.3 Ionizers supply positive and negative ions to neutralize either polarity of static charge. Ionizers should be carefully balanced to avoid generating a charge on isolated conductive objects. Ionizers that are incorrectly balanced or badly maintained may create a risk rather than reducing the risk. Refer to ESD Association documents ANSI/ESD STM3.1, ANSI/ESD SP3.3, and ESD TR3.0-02-05 for more information regarding the use and testing of air ionization.

10.2.3.4 Regular monitoring of ionizer efficiency and balance is recommended for the effective operation of an EES handling zone. The frequency of checks depends on many factors including the inherent stability of the ionizers being used, so it cannot be recommended in this Document. Operators of EES zones should satisfy themselves that auditing intervals and monitoring methods are adequate to maintain the effective operation of ionizers.

10.2.4 *Field Mitigation*

10.2.4.1 *Field Reduction*

10.2.4.1.1 Avoiding the accumulation of static charge should minimize electric fields. This may be best done through the careful selection of materials and by employing air ionization as described previously.

10.2.4.1.2 Corona-type air ionizers work by generating strong electric fields at emitter tips. Care should be taken to ensure that any electric fields produced by such air ionizers cannot reach an EES item. Alpha or x-ray ionizers produce no strong fields so may be more suitable for use close to EES items.

10.2.4.2 *Shielding*

10.2.4.2.1 Ionizers cannot neutralize the electric fields that are generated by powered systems. So wherever power is used, steps should be taken to minimize stray electric or electromagnetic fields by using shielding.

10.2.4.2.2 Shielding with metal is recommended to achieve the best electric and electromagnetic field reduction around powered systems and great care should be taken when making joints in the shield to ensure that high frequency fields cannot escape. Methods and materials that are suitable for electromagnetic interference (EMI) shielding purposes are preferred for shielding in an EES zone.

10.2.4.2.3 The only fail-safe means of protecting an EES item from externally generated electric and electromagnetic fields may be to enclose it within a fully conductive Faraday cage. Such a field-protective, EES minienvironment carrier should be used to house EES items whenever possible.

10.2.4.2.4 Shielding efficiency is dependent on the conductivity and density of the material that is used to make the shield. Inherently ‘conductive’ or metallized plastics and even metal wire meshes may not be sufficient to achieve