# SEMI E35.1-95 (Withdrawn 0304)
# GUIDE FOR COST OF EQUIPMENT OWNERSHIP COMPARISON METRIC

**NOTICE:** This document was balloted and approved for withdrawal in 2004.

## 1 Purpose

1.1 The purpose of this guide is to provide a standard constrained version of the Cost of Ownership for Semiconductor Manufacturing Equipment Metrics Guide to provide a baseline metric for comparing cost effectiveness of competitive factory equipment subsystems in the semiconductor industry. The major constraints are the inclusion of only Equipment Yield and the exclusion of the Cost of Yield Loss consisting of defect limited yield and parametric yield.

1.2 The guide establishes well-defined practice to facilitate cost comparisons of equipment by using definitions, classifications and methods necessary to build a useful cost of equipment ownership comparator as a constraint version of SEMI E35. The guide should facilitate communication about cost of ownership.

## 2 Scope

2.1 This guide is a subset of a full COO calculator as presented in SEMI E35 and constitutes a fully conforming standard constraint version. The baseline metric is meant to reflect those equipment aspects over which an equipment supplier has responsibility and seeks to minimize aspects which couple costs for individual equipment to the entire factory system. The use of the metric is for competitive evaluation of equipment sets to be used for a specific process step.

2.2 Effective use of the metric to build a COO model requires identification of the constraints, parameter values within the adopted category classification. The primary calculators should, where possible, use direct values for inputs rather than deriving them from secondary models or using the default values provided in Related Information 1 and 2 in SEMI E35. A COO model requires data for many parameters. Default data for the COO is provided within this document and may be updated periodically through support documents.

## 3 Referenced Documents

3.1 *SEMI Documents*

*SEMI E10* — Guideline for Definition and Measurement of Equipment Reliability, Availability, and Maintainability

*SEMI E35* — Guideline for Cost of Ownership for Semiconductor Manufacturing Equipment Metrics

SEMI Compilation of Terms

## 4 Terminology

All terminology in this guideline is defined in SEMI E35.

## 5 Cost of Equipment Ownership Comparator

The Cost of Equipment Ownership Comparator (CEOC) metric is the incremental cost added to a good wafer or IC device flowing through a volume sized process system embedded in a factory environment for a specified lifetime. The metric is expressed as Cost per Good Wafer Equivalent for one pass through the system. CEOC should reflect the full cost of embedding and operating in a factory environment a process system needed to accommodate a specified number of wafers but does not include defect yield or parametric yield loss.

5.1 *CEOC: Fixed and Recurring Costs* — Determining the Cost of Ownership requires enumerating all of the Fixed and Recurring costs. Fixed costs are those incurred once and are usually associated with the acquisition and incorporation of equipment into the factory. Recurring costs are those which arise on an annual basis from the operation and maintenance of the equipment.

5.2 *Yield*

5.2.1 Production yield (PY) is often tied to a large number of factors which are principally the responsibility of the IC manufacturer and equipment comparisons for production yield should be done directly in the context of the production flow. Yield is a metric of the percentage of the wafer volume that results in good wafers and enters the picture in a number of ways which can complicate comparisons. Yield-related comparisons of equipment should be dealt with directly rather than lumping them into the CEO.

$$\text{CEO} = \overbrace{\left(\begin{matrix}\text{annualized}\\ \text{Fixed Costs}\\ \text{per system}\end{matrix} + \begin{matrix}\text{annualized}\\ \text{Recurring Costs}\\ \text{per system}\end{matrix}\right)}^{\substack{\text{COST of}\\ \text{Embedding + Operating}}} * \frac{\substack{\text{Volume Required}\\ \text{\# Systems}}}{\substack{\text{Good Units}\\ \text{Per Year}}}$$

5.2.2 Particles additions for example are often used as a predictor of yield loss. Equipment should be compared directly on the basis of particles or other direct metrics such as uniformity.

5.2.3 The Cost of Equipment Ownership should only reflect Equipment Yield. The percentage of wafers which can be passed to the next step can be based on any criteria, such as broken wafers or wafers determined to be defective by inspection or test.

5.3 *Life* — Time over which the fixed and recurring costs are spread for the annualized basis. Tax Life is customarily used in COO based upon standard accounting practice.

**COO Lifetimes**

1. Tax Lifetime - Depreciation
2. Equipment Production Lifetime

5.4 *System Throughput* — Wafers per hour capability for the process system.

5.5 *Volume Requirement*

5.5.1 The volume requirement is the wafer or IC (unit) flow to be processed. The volume requirement can be derived from specification of the product wafers or IC devices needed corrected for yield and the required number of other wafers which might be designated as test, dummy, or monitor wafers. One complication in accurately dealing with the volume requirement is that the volume of wafers actually reaching the equipment will depend on the volume loss from equipment yield for all the prior steps.

5.5.2 For CEOC, volume should be dealt with parametrically based upon factory wafer starts. For multi-chamber equipment, the impact of added chambers to increase capacity should be included as well as the impact of adding whole systems.

5.6 *Good Wafer Equivalents (GWE)* — GWE is derived from the number of good product die at wafer probe and is expressed as completely good wafers.

5.7 *Systems Required* — See SEMI E35.

## 6 Reporting Results

Conform to SEMI E35.

## 7 Limitations

7.1 Certain factors are more difficult than others to accurately determine. Thus, the accuracy of a COO calculation may be prone to a variety of errors or omissions. In addition, line balance considerations are not included in cost of ownership calculation.

7.2 A COO calculation may have more detail than presented explicitly in this guide. The structure of the guide however allows for the proper handling of these situations.

## 8 Procedures

8.1 The CEOC algorithm requires the specification of the volume level and the enumeration of appropriate fixed and recurring costs associated with processing that volume. The CEOC metric is a function expressed as the sum of a number of categories which constitute a classification system as given in SEMI E35. Each item in the classification system should be defined, a method for evaluating its expression given, and default values or handling specified. The cost of equipment ownership is a sum over the elements in the Category Table as expressed in Equation 2 and defined in SEMI E35.

8.2 Each item in the classification system is defined, a method for evaluating its expression given, and default values or handling specified. All costs must be assigned through the classification system and calculated per system for the number of production hours.

$$\mathrm{CEOC} = \left(\sum_j F_{0j} + \sum_k R_{0k}\right) * \left(\frac{\dfrac{\text{Volume Required}}{\#\ \text{Systems}}}{\dfrac{\#\ \text{Good Units}}{\text{per year}}}\right) = \left(\sum_{ij} F_{ij} + \sum_{kl} R_{kl}\right) * \left(\frac{\dfrac{\text{Volume Required}}{\#\ \text{Systems}}}{\dfrac{\#\ \text{Good Units}}{\text{per year}}}\right) \qquad (2)$$

# SEMI E43-0301
# GUIDE FOR MEASURING STATIC CHARGE ON OBJECTS AND SURFACES

This guide was technically approved by the Global Metrics Committee and is the direct responsibility of the North American Metrics Committee. Current edition approved by the North American Regional Standards Committee on November 22, 2000. Initially available at www.semi.org December 2000; to be published March 2001. Originally published in 1995.

This document was entirely rewritten in 2001.

## 1 Purpose

1.1 The purpose is to establish a guide for reproducible measurement of electrostatic charge(s) on any surface or object, consistent with the scope and limitations set forth below.

## 2 Scope

2.1 The measurement methods described herein can be applied to characterize the general electrostatic charge level(s) on objects and surfaces in all environments. Acceptable instrumentation, calibration, and measurement techniques are described in this document. Appendices include background information on the equipment specified and calibration procedure, as well as information and advice on performing a useful general static survey.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety health practices and determine the applicability or regulatory limitations prior to use.

## 3 Limitations

3.1 Direct measurement of charge usually requires the use of a coulombmeter. Charges on an isolated conductor can be measured by transferring the charge into the coulombmeter by contacting the isolated conductor with the coulombmeter input probe. Charges on isolated conductors and insulators can be measured by transferring the charged object into a Faraday enclosure that is connected to the coulombmeter. These measurements can be relatively precise if care is taken in the transfer process to avoid changing the charge level when making the measurements.

3.2 Direct measurement of charge is often impractical. In these instances, charge is indirectly evaluated by detecting the electrostatic field from a charged surface using an electrostatic fieldmeter or an electrostatic voltmeter.

3.3 This guide does not describe instrumentation and techniques capable of making highly precise measurement of electrostatic charge. It is not suitable for measurement of electrostatic charge on small objects, such as packaged devices (i.e., reading(s) obtained are indicative/general area and not precise/ minute). No methods of preconditioning the surface prior to measurements and no methods of characterizing the basic electrostatic performance of materials, such as tribocharging, resistance, and decay rate are a part of this document. Measurements made using this guide on the same surface or object may differ due to differences in the environment or history of the surface or object between the times any two measurements are made.

## 4 Referenced Standards

4.1 None.

## 5 Terminology

5.1 *electrostatic discharge (ESD)* — the rapid spontaneous transfer of electrostatic charge induced by a high electrostatic field.

5.2 *ground* — a conducting connection between an object, electrical equipment, and earth, such as the portion of an electrical circuit of the same electrical potential as earth.

5.3 *grounded* — connected to earth or some other conducting body that serves in the place of earth.

## 6 Safety

6.1 *Measurements of Very High Static Potentials (> 30,000 Volts)* — Measurements of very high static potentials (> 30,000 V) may need to be done at larger distances to avoid exceeding the measurement range of the meter and/or an ESD event to the meter.

6.2 *Measurements on Moving Objects or Surfaces* — Care should be taken, when attempting to read electrostatic charges on moving objects or surfaces, to maintain correct distance and avoid any contact; this is to assure “good” readings with no mechanical damage or personal injury.

6.3 *Measurements Using Electrostatic Voltmeters* — Avoid handling electrostatic voltmeter probes during operation as their surfaces may be at elevated potentials that represent a shock hazard to the operator.

## 7 Equipment and Performance Verification Methods

7.1 *Equipment*

7.1.1 *Electrostatic Locator/Field Sensor/Field Meter* — An electrostatic fieldmeter measures the value of the electrostatic field at its sensor. Electrostatic fieldmeters are calibrated and recommended for use at a particular distance from the charged object. Fieldmeters are best suited for making general surveys or audits, for making measurements of surfaces at very high potentials *(charge levels)*, and for making measurements when long-term stability is not important. They are not well suited for measurements of surfaces with very low potentials or when high spatial resolution of the surface potential is needed.

7.1.1.1 The electrostatic locator/field sensor/field meter will henceforth be referred to as "the fieldmeter." Note that for measurements to be taken in the presence of air ionization, a chopper stabilized fieldmeter is required. The fieldmeter must be capable of making field measurements at a distance of 2.54 centimeters (cm) = 1 inch or less, from the field source to the sensor for this guide, as written. However, see Section 7.2.5 for fieldmeters that are operated at fixed distance(s), and adjust values in this document where applicable.

7.1.2 *Electrostatic Voltmeter* — An electrostatic voltmeter nulls the electrostatic field at its sensor (probe). An electrostatic voltmeter indicates the presence and approximate level of the charge(s) creating the electrostatic field. Under appropriate conditions, electrostatic voltmeters provide a better approximation of the charge level as compared to electrostatic fieldmeters. Electrostatic voltmeters are relatively free of drift and more environmentally stable as compared to fieldmeters.

7.1.2.1 Electrostatic voltmeters are well suited for fixed installation in equipment. Electrostatic voltmeters exhibit a high degree of accuracy that is independent of the distance from the charge. Thus, they are considered better suited for making more accurate and repeatable measurements as compared to fieldmeters. The probe can be located very close to a charged surface without arc-over, and, under appropriate conditions, can resolve a small spatial area on a surface.

7.1.2.2 Electrostatic voltmeters are best suited for making measurements of surfaces at potentials below 20kV, or when a calibrated or fixed distance from the probe to the surface cannot be maintained. They are also best suited for measuring low surface potentials, or when it is desired to resolve a small area on the surface. Electrostatic voltmeters are unsuitable for measuring surfaces at very high potentials, such as above 20kV.

7.1.2.3 The electrostatic voltmeter will henceforth be referred to as "the voltmeter."

7.1.3 *Electrometer* — An electrometer is a contact voltmeter with a very high input impedance. Ideally, this input impedance would be infinite. In practice, it is limited by intrinsic physical materials properties of insulators and by stray leakage paths between the input terminals. Low voltage electrometers (below 200 Volt) have typical input resistances of $10^{14}$ ohms, accuracies better than 0.1%, and can resolve microVolt type potentials. High voltage electrometers (Kilovolts) usually rely on resistive voltage dividers and have typical input resistances in the $10^{11}$ ohms range with accuracies in the 1% range. It is important to evaluate and understand the burden that the input impedance of an electrometer represents when measuring voltage potentials on very small charged structures.

7.1.4 *Charged Plate Monitor* — A charged plate monitor is an instrument typically used to monitor the performance of air ionization equipment. Monitoring is done with an electrically isolated 15 cm × 15 cm (6 inches × 6 inches) metal plate, henceforth referred to as "the plate." The instrument typically provides a means to charge the plate to a known voltage (1000 or 5000 volts of either polarity), a plate sensor to determine the voltage on the plate, and timing circuitry to determine the time required to discharge the plate to a percentage of its initial charge. For the purposes of this guide, the charged plate monitor, or a separate isolated plate assembly, can be used for performance verification purposes as explained in Section 7.2.

7.2 *Equipment Performance Verification (Confidence Test)*

7.2.1 *Performance Verification of a Coulombmeter* — Refer to Figure 1.

7.2.1.1 Zero the coulombmeter prior to each measurement.

7.2.1.2 Maintain a reference calibration capacitor. It should be a polystyrene or polypropylene 10 nF capacitor (Mallory SX-110 or equivalent). Measure the value of the capacitor to better than 1%. It is important to handle the reference calibration capacitor very carefully. Do not hold the capacitor by its body or discharge it by touching both leads with the fingers. Hold the capacitor by one lead only. Use a clip lead connected between ground and this lead of the capacitor to maneuver the other lead of the capacitor between the "hot" side of the charging source and the input terminal of the coulombmeter.

7.2.1.3 Charge the reference calibration capacitor to 1 volt with a charging source (power supply). Calculate the amount of charge on the capacitor by multiplying the voltage by the value of the capacitor. Example: 1V x 10 nF = 10 nC of charge.

7.2.1.4 Disconnect the charging source from the capacitor.

7.2.1.5 Connect the coulombmeter input probe to the capacitor and discharge the capacitor into the coulombmeter. The coulombmeter should indicate the calculated value.

7.2.2 *Performance Verification of Fieldmeters and Voltmeters* — Refer to Figure 2.

7.2.2.1 *Choosing Test Voltage(s)* — Choose one or more test voltage(s) from Table 1, based upon the electrostatic field level of concern:

**Table 1 Test Voltages**

| *Field of Concern* | *Test Voltage* |
|---|---|
| Under 4,000 volts/meter or 100 volts/2.5 cm | 100 volts |
| Under 40,000 volts/meter or 1000 volts/2.5 cm | 1,000 volts |
| Over 200,000 volts/meter or 5,000 volts/2.5 cm (See NOTE 1.) | 5,000 volts |

NOTE 1: If fieldmeter or voltmeter performance verification is needed above 5,000 volts, it is left to the user to select values using the table as guide.

7.2.2.2 *Instrument Performance Verification* — Charge a conductive test plate to the desired verification voltage. Use of a suitable power supply or a charged plate monitor for test purposes is recommended.

7.2.2.3 *Assuring Meters and Operator Are Grounded* — Assure that the fieldmeter, voltmeter and operator are grounded. Turn on the meter and zero it as required according to manufacturer's instructions.

7.2.2.4 *Directing or Pointing the Sense Head* — Direct or point the sense head of the fieldmeter or voltmeter at the center and parallel to the surface of the plate at a distance at least twice the manufacturer's recommended measurement. Slowly move the sense head toward the center of the charged plate until a reading equal to the voltage applied to the plate in Section 7.2.2.1 above is displayed by the meter. Measure and record the distance from the sense head to the surface to the plate. Using the plate voltage from Section 7.2.2.1 above and the recorded distance, compute the field strength for the fieldmeter. See Figure 2, Fieldmeter and Voltmeter Verification Check.

7.2.2.5 *Alternative to Section 7.2.2.4* — Take measurements at a specified/fixed distance per manufacturer's instructions. Locate the sense head of the fieldmeter or voltmeter as in Section 7.2.2.4, but, at specified distance; reading displayed (on meter) should be within 5% of applied voltage to plate.

NOTE 1: Section 7.2.2.4 or 7.2.2.5 should be applicable to most meters. However, in every case, the electrostatic fieldmeter or voltmeter manufacturer's instructions should be read, understood, and followed.

7.2.2.6 *Other Desired Test Voltages* — Repeat Sections 7.2.2.4 and 7.2.2.5 for any other desired test voltages.

7.2.3 *Performance Verification of an Electrometer* — It is good practice to occasionally check the performance of the electrometer by connecting it to a known voltage source, and comparing its readings with readings taken by another reference voltmeter.

7.2.4 *Meter Stability* — All measurement devices should be turned on and pre-conditioned for as long a warm-up period as recommended by the manufacturer

7.2.4.1 Reset (zero) the coulombmeter prior to each measurement.

7.2.4.2 Check the zero on the fieldmeter or voltmeter as specified by the manufacturer. Usually this is done while the probe is positioned to view a grounded surface. If the zero of the meter has drifted by more than 5% of the test voltage for any range contained in Table 1, the meter is not suitable for use for measurements over that range. It may be suitable for use over other ranges contained in Table 1, using other test voltages. Reverify the meter's calibration at the selected test voltage.

7.2.4.3 *Zeroing an Electrometer* — Except on some older analog models, there are usually no provisions to zero an electrometer. Some electrometers with analog or digital read-outs do allow offsetting of a reading, as well as relative (delta) measurements. However, the electronic zero of the electrometer is usually set by the manufacturer, and should be part of the normal calibration. It is good practice to occasionally check the zero by shorting the input terminals together and verifying that the zero reading is within the manufacturer's specifications.

7.2.4.4 See Related Information 1 for notes on equipment accuracy and limitations.

## 8 Sampling

8.1 Sampling methods for this guide should be determined by the requirements of the user's application. Electrostatic surveys can be repeated at different times to make them more representative of actual static charge conditions in the surveyed area. The results will vary due to environment (e.g., humidity) and workstation setup/conditions. However, any measurement that is in excess of a (user) defined maximum or that is a benchmark value, should be repeated more than once, after performing a zero check of the measuring equipment. This is to validate previous reading(s) and/or establish a range/bounds in the case of varying-moving fields on previous reading(s).

## 9 Test Methods & Measurements

9.1 *Coulombmeter Measurements*

9.1.1 *Verifying the Coulombmeter* — Verify the performance of the coulombmeter as in Section 7 above. Check/reset the zero before each measurement and/or per manufacturer's instructions. Assure that the coulombmeter and operator are grounded.

9.1.2 *Equipment Selection* — Use a coulombmeter for direct measurement of charge. A feedback-type coulombmeter is recommended for charge measurements for the most complete transfer of charge. Shunt-type coulombmeters do not completely transfer charge and are not as straightforward to use as feedback-type coulombmeters. When using a Faraday enclosure, the Faraday enclosure must be large enough to hold the objects to be measured. The Faraday enclosure is used to measure charge on insulating materials as well as on conductors.

9.1.3 *Measurements* — Best results are achieved when all surfaces surrounding the measurement area are grounded (to minimize the effects of stray fields on the measurement) and when a consistent, systematic handling method is used during the measurement process. The operator should be grounded using a grounded wrist strap.

9.1.3.1 *Isolated Conductors* — To measure the charge on an isolated conductor, touch the lead from the coulombmeter to the isolated conductor.

9.1.3.2 *Faraday Enclosure Measurements* — Refer to Figure 3. To measure the charge on an object, carefully pick up the object with an insulated tool and place the charged object into the Faraday enclosure. Special handling considerations: Be careful not to add or subtract any charge in the process of moving the charged object into the Faraday enclosure. Don't let the charged object rub or slide against any other surface, as this may add or subtract charge from the object.

9.1.4 *Limitations* — Do not attempt to measure charges of magnitudes that are below the drift rate of the coulombmeter.

9.2 *Electrostatic Fieldmeter Measurements*

9.2.1 *Verifying the Fieldmeter* — Verify the performance of the fieldmeter as in Section 7 above. Check/reset the zero periodically and/or per manufacturer's instructions. Assure that the fieldmeter and operator are grounded.

9.2.2 *Measurements* — Measurements made to this guide should be taken/reported in units that conform to the customer specifications. Most common fieldmeters manufactured to date have operating instructions that reflect the user doing calibration and taking measurements in English units of volts/inch or volts at a fixed distance in inch(es) and in these cases, raw data are reported/listed directly. The international community specifies that units shall be in SI (Standard International) Metric units and the SI conversion factor in Section 7.1.1.1 will apply. However, by definition, electric field is expressed in volts per meter, and thus would be expressed according to Table 2.

9.2.2.1 For instance, when using a meter calibrated only at 100 volts, measurements under 4,000 volts/m would be expressed to the nearest 400 volts/m. Measurements over 4,000 volts/m would be expressed as > 4,000 volts/m. For a meter calibrated to all three voltages, measurements under 4,000 volts/m would be expressed to the nearest 400 volts/m, measurements between 4,000 and 40,000 volts/m would be expressed to the nearest 4,000 volts/m, and measurements over 40,000 volts/m would be expressed to the nearest 40,000 volts/m.

**Table 2 Measurement Units**

| *Test Voltage* | *For Readings of* | *Express in Multiples of* | *For Readings of* | *Express as* |
|---|---|---|---|---|
| 100 V | < 4,000 V/m | 400 V/m | > 4,000 V/m | > 4,000 V/m |
| 1,000 V | < 40,000 V/m | 4,000 V/m | > 40,000 V/m | > 40,000 V/m |
| 5,000 V | < 200,000 V/m | 20,000 V/m | > 200,000 V/m | multiples of 200,000 V/m |

Note: Measurements above 1000 volts/2.54 cm may be made based on verification of the meter at 1000 volts where less precision is acceptable due to safety concerns with verification equipment/setup or availability of such equipment.

9.2.3 *Measurement Limitations* — Measurements made to this guide are only valid for surfaces that are flat to a radius of 1.5 times the measurement distance from a point directly below the sensor head. For surfaces that are not flat, measurements should be made by moving the sensor over the surface such that the specified measurement distance is maintained as closely as possible. These measurements may only be stated as a range, with rounding as applicable to the meter's measurement range according to Section 9.2.2. See Figure 4, Example of a Survey of a Carrier of Semiconductor Wafers. See Related Information 2 for notes on test methods environment and measurements.

9.3 *Electrostatic Voltmeter Measurements* — Refer to Figure 4.

9.3.1 *Verifying the Voltmeter* — Verify the performance of the voltmeter as in Section 7 above. Check/reset the zero periodically per manufacturer's instructions. Assure that the voltmeter and operator are grounded.

9.3.2 *Selecting the Voltmeter* — Select an electrostatic voltmeter with a measurement range consistent with the anticipated levels of charge on the objects to be measured. The selection of too high a measurement range will sacrifice voltage resolution, while selection of too low a range will cause out-of-range operation (saturation).

9.3.2.1 To measure moving objects, select an electrostatic voltmeter with a response speed fast enough to detect the objects when they are moving past the electrostatic voltmeter probe at the highest anticipated velocity.

9.3.2.2 Select a side- or end-viewing probe for the electrostatic voltmeter as is best suited to view the target object or surface when the probe is installed in an apparatus.

9.3.3 *Measurements* — Position the probe in front of the surface to be measured. Best results are obtained when the probe is placed less than two (probe) aperture diameters from the object or surface to be measured. At these closer spacings, the effects of extraneous fields are minimized.

9.3.3.1 To resolve a small surface area, the distance between the probe and the surface-under-measurement must be less than 1/5$^{th}$ of the diameter of the surface area to be measured. At wider spacings the surface area resolved by the probe will exceed the surface area of interest, and measurement accuracy may be reduced together with the possibility of introducing effects of extraneous fields to the measurement.

9.3.4 *Measurement Limitations* — Voltage levels on isolated conductors can be measured. Insulators do not have a uniform surface charge distribution. Therefore, it is considered that voltage levels measured on insulators indicate an electrostatic field strength in a particular area.

9.4 *Electrometer Measurements* — Measuring with an Electrometer is very similar to measuring with any other voltmeter or multimeter.

9.4.1 Connect the “common” terminal of the electrometer through a test lead to the reference plane or ground. Connect the “hot” or signal lead to the object or test point of interest. Some electrometer measurements will use a separate wire or shield connected to the electrical ground or a guard ring. Connect this as recommended by the manufacturer of the equipment.

9.4.2 The major difference between the ordinary voltmeter and the electrometer is the orders of magnitude higher input impedance of the electrometer. An electrometer will therefore pick up voltage signals produced by stray electric fields, potentials associated with noise currents, and artifacts caused by intentional or unintentional ionization of the ambient air when measuring high voltages. An electrometer can, for example, be used to measure the triboelectric and the piezoelectric properties of a piece of coaxial cable: connect the cable under test to the electrometer, and flex it or tap on it with a finger. The voltages induced on the center conductor can be measured by the electrometer.

## 10 Certification

10.1 Certification to survey areas to this guide is for the person doing the certification (certifier) to assure that the person being certified (certifyee) can calibrate the meter and make acceptable measurement of known static field(s) per Section 7 and applicable example(s) per Section 9. The certifier shall be someone qualified by education and/or training to calibrate and make measurements with the equipment called out in this guide or someone previously certified. The ESD Association conducts such training programs and the National Association of Radio and Television Engineers (NARTE) administers an ESD Engineer and ESD technician certification program.

10.2 *Demonstrating Ability to Verify the Performance of the Meter Against Known Source* — The certifyee shall charge the test plate, zero the meter, and perform the measurement a minimum of two times per Section 7; record values per Section 11. Readings obtained shall be within 5% of expected values.

10.3 *Demonstrating Ability to Measure Example Item(s) Acceptably* — The certifier will have charged/uncharged example(s) of items/objects for measurement of static field(s) by certifyee(s) a minimum of two times per Section 9; record values per Section 11.

10.4 *Certifying* — Readings obtained per Section 10.2 shall be within 12% of expected values and methodology of obtaining readings shall be acceptable per certifier observation(s). A permanent record of certification is realized by certifyee when certifier signs record sheet(s) for file in personnel records and/or when certifier issues a certificate. Refer to Section R1-3.

## 11 Documentation

11.1 Meter calibration check(s), benchmark or laboratory measurements, items/areas surveys, and/or any other electrostatic field measurements should be recorded in permanent records. Recorded are initial reading, second/validation reading, and any subsequent readings taken to acceptable range/bound levels observed. Record sheet(s) should show meter used, area (name), location, date, and items listed opposite readings, name of person who took readings, and space for comments.

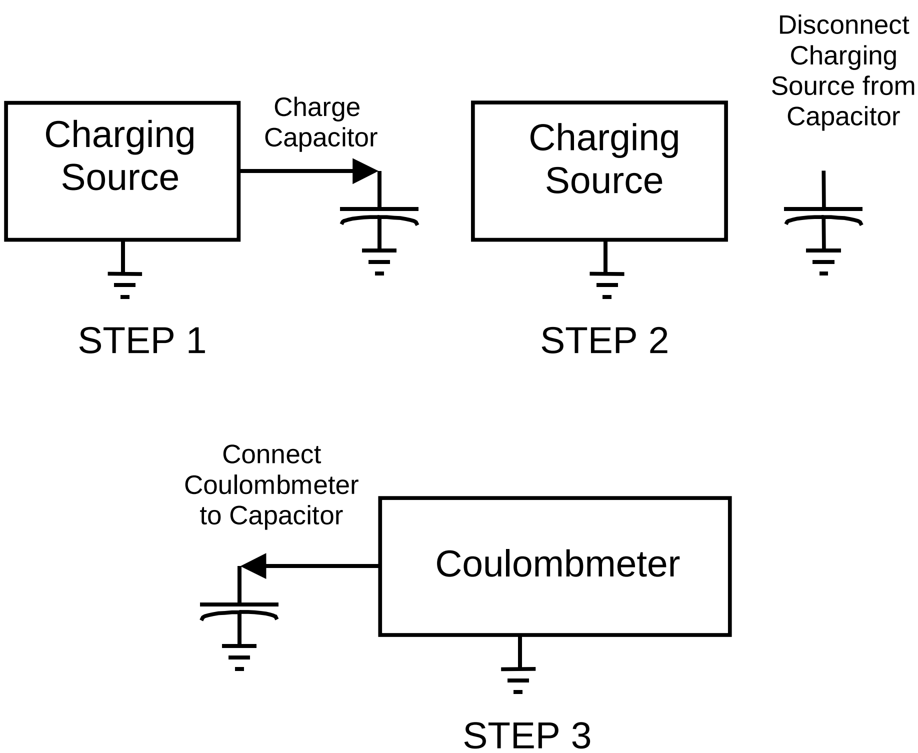


**Figure 1**
**Verifying Performance of the Coulombmeter**

A) Connect meter directly to charged plate ground reference.
B) Meter approximately 2.54 cm and parallel to charge plate.
C) Meter reading should be within 5% of voltage applied to plate.
D) Assure that both the meter and the operator are properly grounded.

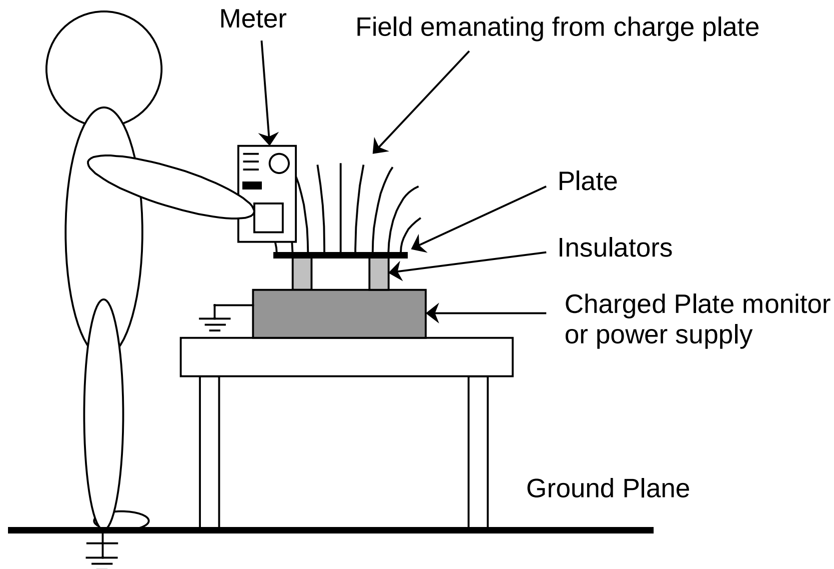


**Figure 2**
**Fieldmeter and Voltmeter Verification Check**

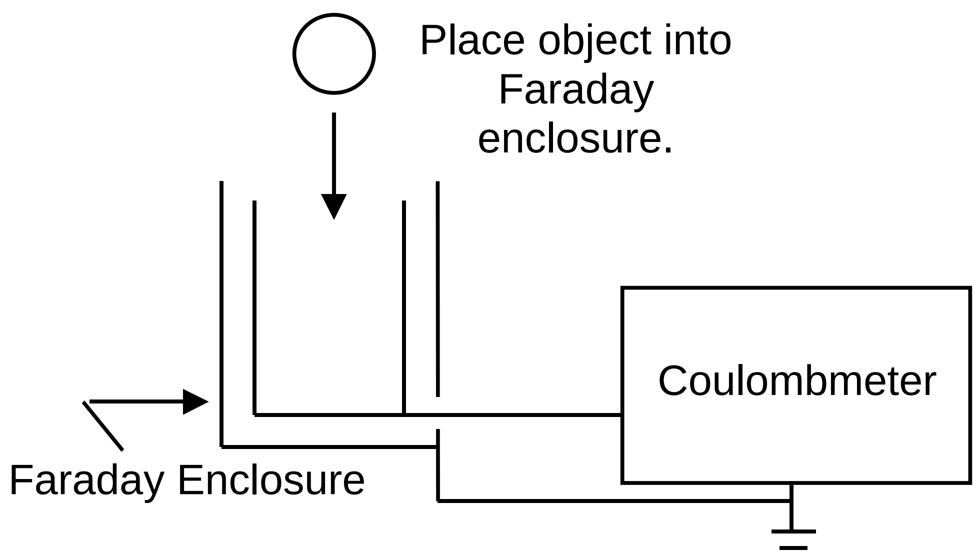


**Figure 3**
**Measurement With a Coulombmeter and Faraday Enclosure**

A) Make sure meter is properly grounded according to manufacturer's instructions.
B) Scan approximately 2.54 cm along both sides and ends of carrier.
C) Scan approximately 2.54 cm length of carrier and top-center of wafers with meter.
D) Note high-low values for B) & C).
E) Assure that the operator is properly grounded.

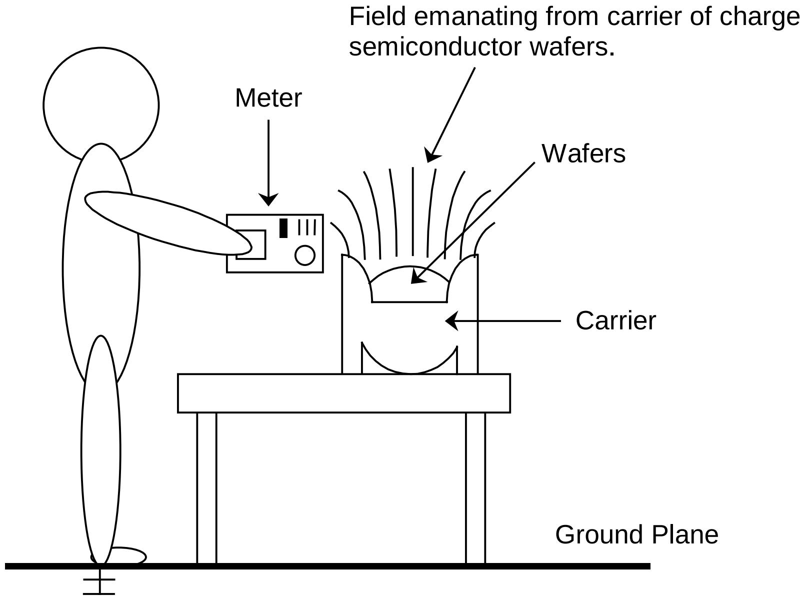


**Figure 4**
**Example of a Survey of a Carrier of Semiconductor Wafers**

## 12 Related Documents

NOTE 2: These documents are for information only; in the case of conflict, this document takes precedence. Also read/be aware of appendices to this document before use.

12.1 *ESD Association Standards*[1]

*ANSI EOS/ESD S3.1: Ionization*. Test methods and procedures for evaluating and selecting air-ionization equipment and systems are provided in this standard, which establishes measurement techniques to determine ion balance and charge-neutralization time for ionizers.

*ESD STM4.2: Worksurfaces — Charge Dissipation Characteristics.* This standard test method prescribes a procedure for measuring the electrostatic-charge-dissipation characteristics or work surfaces used for ESD control.

1 ESD Association, 7900 Turin Rd., Bldg. 3, Suite 2, Rome, NY 13440-2069, website: www.esda.org

*ESD STM5.1: ESD Sensitivity Testing — Human Body Model.* This standard test methods defines procedures for testing, evaluating, and classifying the ESD sensitivity of components to the defined Human Body Model (HBM).

*ESD S5.2: ESD Sensitivity Testing — Machine Model.* This standard established a test procedure for evaluating the ESD sensitivity of components to a defined Machine Model, and outlines a system whereby the sensitivity of such components may be classified.

*ESD STM5.3.1: ESD Sensitivity Testing — Charged Device Model.* This standard is a test method for evaluating active and passive components' ESD sensitivity to a defined Charged Device Model.

*ANSI/ESD S20.20: ESD Control Program.* This standard specifies the requirements that must be satisfied in designing, establishing, implementing, and maintaining ESD control programs for ESD-sensitive items susceptible to discharges equal to or greater than 100 V HBM.

*ESD SP10.1 — Automated Handling Equipment.* This document covers test methods for evaluating the ESD ground integrity of automated handling equipment as well as charge generation, and charge accumulation on devices in automated handling equipment.

12.2 *ESD Association Advisory Documents*

*ESD ADV1.0 — Glossary of Terms.* Definitions and explanations of various terms used in Association Standards and documents are covered in this advisory. It also includes other terms commonly used in the ESD industry.

*ESD ADV2.0 — ESD Handbook.* The ESD Handbook is a complete guide to static control in the work place. Nineteen chapters cover ESD basics, control procedures, auditing, symbols, device testing, and standards.

*ESD ADV11.2 — Triboelectric Charge Accumulation Testing.* The complex phenomenon of triboelectric charging is discussed in this Advisory. It covers the theory and effects of tribocharging. It reviews procedures and problems associated with various test methods that are often used to evaluate triboelectrification characteristics.

12.3 *Other Related Documents*

12.3.1 *Military Standards*[2]

*MIL-STD-1686C: ESD Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Devices).* This military standard establishes requirements for ESD control programs. It applies to U.S. military agencies, contractors, subcontractors, suppliers, and vendors. It requires the establishment, implementation, and documentation of ESD control programs for static-sensitive devices but does not mandate or preclude the use of any specific ESD control materials, products, or procedures.

*MIL-HDBK-263B: ESD Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (excluding Electrically Initiated Explosive Devices).* This reference provides guidance, but not mandatory requirements, for the establishment and implementation of an ESD control program in accordance with the requirements of MIL-STD-1686.

2 Naval Publication and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120 U.S.A

12.3.2 *JEDEC Standards*[3]

*JESD625A: Requirements for Handling ESD-Sensitive Devices.* This voluntary standard establishes minimum requirements for ESD control methods and materials designed to protect electronic devices having Human Body Model (HBM) sensitivities of 200 V or greater. It is intended for use by semiconductor distributors, semiconductor processing and testing facilities, and semiconductor end users.

12.3.3 *EIA Standards*[4]

*EIA 541 – Packaging Material Standards for ESD Sensitive Items* — This standard presents requirements and tests methods for selecting packaging materials to be used with ESD sensitive devices.

*EIA 583 – Packaging Material Standards for Moisture Sensitive Items* — This standard contains information regarding packaging materials used for the protection of ESD sensitive items when moisture levels are also important.

*EN100015: Protection of Electrostatic Sensitive.* This European Norm covers ESD handling practices for electronic devices.

12.3.4 *IEC Standards*[5]

*IEC 61000-4-2 – Transient Immunity Standard.* This IEC document provides requirements and test methods for ESD transient immunity.

*IEC 61340-5-1:1998, Electrostatics, Part 5-1: Protection of Electronic Devices from Electrostatic Phenomena-General Requirements.* This IEC (International Electrotechnical Commission) document provides guidance for establishing a static control program.

*IEC 61340-5-2:1999, Protection of Electronic Devices from Electrostatic Phenomena-Users Guide.* This IEC handbook supplement the information contained in Part 5-1 above.

3 Joint Electron Device Engineering Council, 2500 Wilson Blvd., Arlington, VA 22201, website: www.jedec.org

4 EIA Engineering Department, Standards Sales Office, 2001 Eye Street, NW, Washington, D.C. 20006, website: www.eia.org

5 International Electrotechnical Commission, 3, rue de Varembé, Case postale 131, CH-1211 Genève 20, Switzerland, website: www.iec.ch

# APPENDIX 1
# MEASUREMENT SELECTION MATRIX

NOTE: This appendix offers information related to selecting the appropriate measurement methods from those contained in this document. It was approved as an official part of SEMI E43 by full letter ballot procedure.

A1-1 The matrix contained in Table A1-1 is intended to assist in the selection of an appropriate measurement method for static charge. Users should note that a variety of measurement methods is available for any given situation. Consult manufacturers of the equipment for additional information concerning its proper use and applicability.

**Table A1-1 Measurement Method Recommendations**

| *Object* | *Electrostatic Fieldmeter* | *Charged Plate Monitor* | *Electrostatic Voltmeter* | *Electrometer* | *Coulombmeter* | *Oscilloscope* | *EMI Detector* |
|---|---|---|---|---|---|---|---|
| Small object/device charge | X | | X | | X | | |
| Surface charge | X | | X | | | | |
| Ionization system charge neutralization | | X | X | X | | | |
| ESD event detection | | | | X | | X | X |
| Human body voltage | X | | X | X | | | |
| Product cart charge level | X | | X | X | | | |
| Chair charge level | X | | X | X | | | |
| Charge decay | X | X | X | X | | | |
| Product material handling | X | | X | X | | | |
| Ionizer Offset Voltage (Balance) | | X | | X | | | |
| Wafer charge | X | | X | | X | | |
| Process equipment – Charge and ESD generation | X | | X | X | | | X |

# RELATED INFORMATION 1
# NOTES ON EQUIPMENT

NOTE: This related information is not an official part of this standard. However, it contains relevant information for using the standard in situations commonly encountered with semiconductor manufacturing facilities and equipment. Determination of the suitability of the material is solely the responsibility of the user.

R1-1 A charged conductive plate establishes a uniform electrostatic field as long as measurements are not made close to the edges and the measurement distance is small relative to the dimensions of the plate. This specification requires meters capable of making field measurements at a distance of 2.54 cm (1 inch) or less from a 15 cm (6 inch) square plate as a practical means to ensure performance verification to a known field.

R1-2 Charged plate monitors using 15 cm square plates with a 20 picofarad capacitance are commonly used to determine the performance of air ionization systems. Isolators are used to assure minimal leakage to ground. A 15 cm square plate of any metal approximately 1 mm thick and isolated from adjacent surfaces using insulative standoffs is a perfectly acceptable substitute.

R1-3 The verification procedure is intended to ensure that the meter used does not drift excessively (less than 5% in 5 minutes) and can repeatedly measure a known field to within 5%. When actually using the meter to do a field survey, maintaining the correct distance from the sensor head to the surface or object being measured becomes the greatest source of error. If the ability of the meter operator to maintain the correct distance is within 10%, then the total error of the measurement would be within about 12% using this calibration procedure (RMS of the 5% drift, 5% repeatability, and 10% distance errors).

R1-4 If two operators using two different meters follow the verification procedure, and they both are able to maintain the correct distance to within 10% as above, then they both would be within 12% of the true field strength when measuring the same surface or object. Taking the RMS of these errors, the two operators using two meters should be within 17% of each other.

R1-5 Many meters read out in volts/inch. 100 volts/inch is about 4,000 volts/m.

# RELATED INFORMATION 2
# NOTES ON TEST METHODS

NOTE: This related information is not an official part of this standard. However, it contains relevant information for using the standard in situations commonly encountered with semiconductor manufacturing facilities and equipment. Determination of the suitability of the material is solely the responsibility of the user.

R2-1 Prior handling and environmental conditions will significantly impact the field strength to be measured. Below are a number of these considerations:

- The presence of nearby grounded surface or object will tend to reduce the measured field strength. This phenomena is known as field suppression and is illustrated in Figure R2-1.
- Ionization of the surrounding air will tend to reduce the measured field strength by neutralizing the static charge on the surface of the object.
- Rubbing or contacting the surface being measured with another object or surface will tend to increase the measured field strength depending upon the tendency of the two materials in question to tribocharge.
- Increasing humidity will tend to reduce the field strength to be measured because it in turn will reduce the magnitude of the charge generated on objects and, over time, assist in the neutralization of charge on objects.
- Projections and sharp protrusions on the object being measured, or nearby objects, will increase the field strength.
- Insulating objects may have very irregular charge distributions.
- As a result of these considerations, a static measurement or survey made using this standard is only useful if these factors are taken into account in a realistic manner. For example:
  - If a surface is only used in a humidity or temperature controlled environment, field strength measurements made under these conditions are the main ones of interest. Measurements made at different humidities may be irrelevant.
  - An object may present close to zero field in an ionized environment, yet when contacted by another object may become highly charged. This charge may persist for a period of seconds or minutes while it is neutralized by the ionized environment. The time required to return the object to its original state may be a parameter of interest.
  - An object resting on a grounded metal surface may have very low external field strength. If the object is picked up and measured the field may be much higher.
  - Objects of irregular shape and size will give highly variable readings, depending on the position of the sensor relative to the object.
  - Dielectric objects may give highly variable readings, depending upon the position of the sensor relative to the charge distribution on the object.
  - The simple act of handling an object while performing a static survey can change the charge on the object. The best results will derive from making sure that objects and surfaces are treated and handled within the bounds of their actual use.
- During equipment verification, maintaining constant/steady voltage is important. If the plate is initially charged and allowed to float, its voltage will change as the meter is moved close to it.

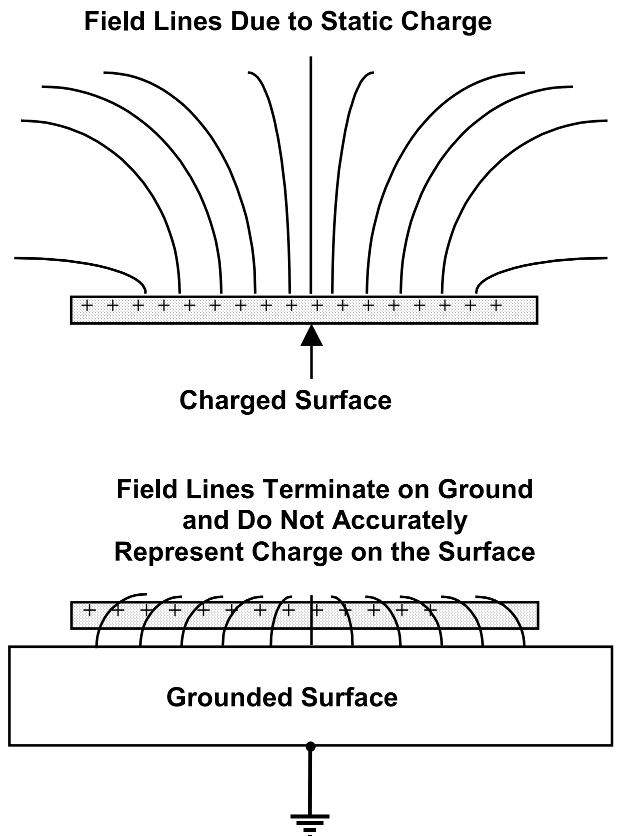


**Figure R2-1**
**Field Suppression**

# RELATED INFORMATION 3
# ESD DAMAGE SIMULATORS

NOTE: This related information is not an official part of this standard. However, it contains relevant information for using the standard in situations commonly encountered with semiconductor manufacturing facilities and equipment. Determination of the suitability of the material is solely the responsibility of the user.

## R3-1 ESD Damage Simulators

R3-1.1 ESD Simulators are used to replicate ESD events. Common types used to characterize semiconductor devices and equipment include:

- Component Level HBM ESD Simulator.
- Component Level MM ESD Simulator.
- Component Level CDM ESD Simulator
- System Level HBM/metal ESD Simulator

R3-1.2 The component level HBM ESD Simulator represents the parameters agreed upon for a standard, which represents the discharge from a typical human body. These parameters are 1500 ohms and 100 pF for the representative resistance and capacitance respectively of the human body.

R3-1.3 The component level MM ESD Simulator represents the parameters agreed upon for a standard, which represents the discharge from a charged metallic arm of a machine (automatic handler etc). These parameters are 200 pF and zero resistance for the representative capacitance and DC resistance respectively of the machine. We note here that the resulting waveform is dependent on the impedance of the circuity.

R3-1.4 The component level CDM ESD Simulator represents the parameters agreed upon for a standard, which represents the discharge from a charged device. These parameters are defined by the resulting waveform and depend almost exclusively on the capacitance, resistance and inductance of each device relative to ground. These parameters must not be confused with the equipment parameters, which affects the resulting waveform.

R3-1.5 The system level HBM/metal ESD Simulator represents the parameters agreed upon for a standard, which represents the discharge from a human holding a metallic instrument. These parameters are the lower resistance 350 ohms and 150 pF for the representative resistance and capacitance respectively of the human holding a metallic instrument. Note here that the waveform is greatly affected by the equipment parasitics.

R3.1.6 The above component level ESD simulators have also been used in simulating ESD damage to tooling, such as reticles and photomasks. This simulation is left to user discretion.

## R3-2 Summary of procedures

R3-2.1 *HBM ESD Simulator-component level* — The procedure for using this simulator to stress test devices or wafers is based upon the standard requirements. ANSI and the ESD Association approved the HBM standard, ESD STM5.1, which contains a specific device pin combination sequence for stress testing. This test procedure is generally referred to as a Pin to Ground test since one pin is always grounded while the selected second pin is stressed. Calibration before use requires added equipment components like a current probe, high bandpass cable, a short wire, a 500 ohm resistor and a very high band width waveform recorder/digitizer.

R3-2.2 *MM ESD Simulator-component level* — The procedure for using this simulator to stress test devices or wafers is based upon the standard requirements. The ESD S5.2 approved MM standard specifies a specific device pin combination sequence for stress testing. This test procedure is also generally referred to as a Pin to Ground test since one pin is always grounded while the selected second pin is stressed. This procedure is exactly the same as for HBM. Calibration before use requires added equipment components like a current probe, high bandpass cable, short wire, a 500 ohm resistor and a very high band width waveform recorder/digitizer.

R3-2.3 *CDM ESD Simulator-component level* — The procedure for using this simulator to stress test devices or wafers is based upon the standard requirements. The ESD STM 5.3.1 approved CDM standard does not use a pin combination procedure. Here the device sits on a charge plate (CP) “dead-bug” style (package on CP and leads/pins vertical) and each pin is discharged successively after each charge to the device package. This procedure is different from that of HBM and MM. Calibration before use requires added equipment components like a capacitance/inductance calibrator, high bandpass cable and a very high band width waveform recorder/digitizer.

R3-2.4 *HBM-metal Simulator- system level* — The procedure for using this hand-held simulator for testing systems (ATE testers, Automatic handlers, computers, printers, ESD Simulators etc) is based upon the standard requirements. The IEC 61000-4-2, 1996 (formally-801-2,1992) standard uses direct contact or air discharge to the system under test and is a different procedure from the other three procedures mentioned above. Calibration before use requires the use of a very large vertical ground plane (at least 4 ft by 4 ft square), a high BW current probe, cables and high bandwidth waveform recorder/digitizer.

## R3-3 Industry Classifications

R3-3.1 *HBM classification*

1. < 250 volts
2. 250 to < 500
3. 500 to < 1000
4. 1000 to < 2000
5. 2000 to < 4000
6. 4000 to < 8000
7. = or > 8000

R3-3.2 *MM classification*

1. M1 < 100
2. M2 100 to < 200
3. M3 200 to < 400
4. M4 400 to < 800
5. M5 = or > 800

R3-3.3 *CDM classification*

1. C1 < 125
2. C2 125 to < 250
3. C3 250 to < 500
4. C4 500 to < 1000
5. C5 1000 to < 2000
6. C6 = or > 2000

R3-3.4 *Hand-Held Metal HBM classification*

*Direct Contact Discharge*

| | Voltage | Current |
|---|---|---|
| 1. | 2,000 | 12.0 amps |
| 2. | 4,000 | 24.0 |
| 3. | 6,000 | 36.0 |
| 4. | 8,000 | 48.0 |

*Air Discharge*

| | Voltage | Current |
|---|---|---|
| 1. | 2,000 | 15.0 amps |
| 2. | 4,000 | 25.0 |
| 3. | 6,000 | 30.0 |
| 4. | 10,000 | 35.0 |
| 5. | 15,000 | 52.0 |

Note that the currents for the same voltage level are not the same for contact versus air discharge.

# RELATED INFORMATION 4
# OTHER METHODS FOR DETECTING STATIC CHARGE AND ESD EVENTS IN EQUIPMENT

NOTE: This related information is not an official part of this standard. However, it contains relevant information for using the standard in situations commonly encountered with semiconductor manufacturing facilities and equipment. Determination of the suitability of the material is solely the responsibility of the user.

## R4-1 Introduction

R4-1.1 Static charge generation is unavoidable whenever materials come in contact. Without a static control program, the problems caused by static charge are also unavoidable. The most common problem caused by static charge is electrostatic discharge (ESD). ESD results in damaged semiconductor ICs, photomask defects, magneto-resistive (MR) read head defects in disk drives, and failures of the drive circuits for flat panel displays (FPD). ESD also creates a significant amount of electromagnetic interference (EMI). Often mistaken for software errors, EMI resulting from ESD interrupts the operation of production equipment. This is particularly true of equipment depending on high-speed microprocessors for control. Results include unscheduled downtime, increased maintenance requirements, and frequently, product scrap. Technology trends to smaller device geometries, faster operating speeds, and increased circuit density make ESD problems worse.[6]

R4-1.2 For many years static control programs concentrated on protecting components from the charge generated on the personnel that handled them. Many static control methods were devised to control the charge on people including wrist and heel straps, dissipative shoes and flooring, and garments. Increasingly, however, the production of electronic components is done by automated equipment, and personnel never come into contact with the static-sensitive devices. Solving the ESD problem means assuring that ESD events do not occur in the equipment used to manufacture and test electronic components.

## R4.2 Static Control in Equipment

R4-2.1 An effective static control program in equipment starts with grounding all materials that might come close to, or in contact with the static sensitive components. This prevents the generation of static charge on machine components and eliminates them as a source of the charge creating ESD events. Care must be taken in a grounding program to assure that moving equipment parts remain grounded when they are in motion. In some cases, static dissipative materials may be substituted for conductive materials where flexibility, thermal insulation, or other properties not available in conductive materials are needed. If charging of components is unavoidable, static dissipative materials may be used to slow the resulting discharges and prevent component damage.

R4-2.2 Most semiconductors use insulating packaging materials such as ceramics and epoxy. Handling these insulating materials inevitably generates static charge, and this charge cannot be removed by grounding the materials. If charge generation is unavoidable, the only effective method of neutralizing the charge on insulators or isolated conductors is to use air ionization. Ionizers are typically mounted in the load stations and process chambers of the automated equipment to neutralize the static charge.

## R4-3 Verifying Equipment Static Control

R4-3.1 A static control program begins when the automated equipment is designed by the OEM, and then continues throughout the lifetime of the equipment. Two basic issues need to be demonstrated. First, are all components in the product-handling path connected to ground? Second, as the product passes through the equipment, is it handled in a way that does not generate static charge above an acceptable level on the component? ESD Association Standard Practice, EOS/ESD SP 10.1-1999[7]. This document contains test methods to verify the integrity of the ground path to equipment parts, as well as to determine if the product is being charged during its passage through the equipment. The test methods are applicable during the original design of the equipment and during acceptance testing by the end user.

R4-3.2 While the test methods of EOS/ESD SP10.1-1999 can also be used for periodic verification of the equipment performance, they have one drawback. The automated equipment must be taken off-line to do the testing. This means that there is lost production time, and often the periodic testing is eliminated to maintain product throughput. Other test methods are available

6 Levit, L. et al, “It’s the Hardware. No, Software. No, It’s ESD! ”, Solid State Technology, May 1999, Pennwell Publishing Company, 98 Spit Brook Road, Nashua NH 03062.

7 EOS/ESD SP10.1 - 1999 “Standard Practice for Protection of Electrostatic Discharge Susceptible Items - Automated Handling Equipment”, ESD Association, 700 Turin Road, Rome NY 13440.

that can be performed with the equipment operating on-line, without altering or disturbing its operation.

## R4-4 ESD and EMI

R4-4.1 When ESD occurs, the discharge time is usually 10 nanoseconds or less. Discharging energy in this short time interval results in the generation of broadband electromagnetic radiation[8], as well as the heat that damages semiconductor components. This electromagnetic radiation, especially in the 10 MHz to 2 GHz frequency range, is the EMI that can affect the operation of production equipment. In addition to ESD damage to semiconductor devices and reticles, ESD-caused EMI results in a variety of equipment operating problems including stoppages, software errors, testing and calibration inaccuracies, and mishandling causing physical component damage.

R4-4.2 *EMI Locators*

R4-4.2.1 When component damage or equipment problems due to ESD are suspected, it may be useful to detect the electromagnetic interference (EMI) generated by the ESD event. This type of testing is both a starting point for determining that static charge has been generated, and it is a measurement point to ascertain that any static control methods have been successful. EMI locators measure dynamic operating conditions, as it is usually not necessary to interrupt equipment operations to make measurements.

R4-4.3 *Types of EMI Locators*

R4-4.3.1 EMI locators are available in a number of different forms. In its simplest form, it consists of an AM radio tuned off station. A popping noise will be heard when an ESD event occurs. At the most complex it consists of a wideband (greater than 1 GHz) digital storage oscilloscope with a set of appropriate antennas, probes, and software. Measurements of radiated interference can be made using antennas while probes can be connected to equipment parts or electronics and power lines.

R4-4.3.2 An oscilloscope attached to a single antenna can assist in pinpointing the actual location of the ESD event.[8, 9, 10, 11] A set of antennas can be used to not only detect the presence of an ESD event, but to determine the location of the pulse in 3 dimensions.[12, 13] Using the same concept as a global positioning system (GPS), the difference in the arrival times of the signal to multiple antennas is directly related to the difference in the distance of each antenna from the ESD source. With the time deltas and the locations of the antennas known, the location of the spark can be uniquely identified employing the appropriate analysis program.

R4-4.3.3 Several other types of EMI locating equipment are currently in use. Most consist of high frequency receiving circuitry followed by level detectors to determine the magnitude of the signal. For the purpose of detecting EMI from ESD events, the equipment should have some way of differentiating the short impulse of EMI from the ESD event from the continuous high frequency radiation of other EMI sources. Some instruments contain a counter to total the number of ESD events above the threshold, or alarms to indicate when the number of ESD events exceeds a preset number. This type of instrument can be placed near a piece of equipment that is suspected of causing ESD events and left in place to monitor.

R4-4.3.4 Several EMI Locators are battery-operated handheld devices that can be easily carried around a facility or placed directly in equipment to check for ESD events. This allows the Locator to detect signals that might otherwise be shielded by the equipment's cover panels. (Note that EMI shielding is usually an important part of the design of most production equipment to prevent radiation from the equipment. This makes the detection of ESD events outside the equipment more difficult.) It allows pinpointing of the location of an ESD event, which can then be correlated to particular machine operations.[8, 14]

R4-4.4 *Limitation in Using EMI Locators*

R4-4.4.1 One caution needs to be observed when using EMI locators to detect ESD events that cause component damage. The signal received by these devices is generated in areas usually surrounded by grounded metal components. It may have to pass through equipment panels and travel some distance through the air before it reaches the detector. There may

8 Tonoya, Watanabe and Honda, "Impulsive EMI Effects from ESD on Raised Floor," 1994 EOS/ESD Symposium, pp. 164-169, ESD Association.

9 Takai, Kaneko and Honda, "One of the Methods of Observing ESD Around Electronic Equipments," 1996 EOS/ESD Symposium, pp. 186-192, ESD Association.

10 Greason, Bulach and Flatley, "Non-Invasive Detection and Characterization of ESD Induced Phenomena in Electronic Systems," 1996 EOS/ESD Symposium, pp. 193-202, ESD Association.

11 Smith, "A New Type of Furniture ESD and Its Implications," 1993 EOS/ESD Symposium, pp. 3-7, ESD Association.

12 Bernier, Croft, and Lowther "ESD Sources Pinpointed by Analysis of Radio Wave Emissions," Journal of Electrostatics (44) pp. 149-157, Nov. 1998, Elsevier Science B.V., P.O. Box 211, 1000 AE Amsterdam Netherlands.

13 Lin, DeChiaro and Jon, "A Robust ESD Event Locator System with Event Characterization," 1997 EOS/ESD Symposium, pp. 88-98, ESD Association.

14 Fujie, A., "Pinpointing Sources of Static Electricity with EMI Locator", Parts 1 and 2, Nikkei Electronics Asia, December 1992 and January 1993, Nikkei Business Publications Asia Ltd., 533 Hennessy Road, Causeway Bay, Hong Kong.

be other radio frequency sources and reflecting or absorbing materials in the area. The actual location of the ESD event may be a considerable distance from the EMI locator. It will be difficult to establish any correlation between the amplitude of the signal received by the EMI locator and the energy in the ESD event that produced the signal. The EMI locator primarily indicates the occurrence of an ESD event and can be used to illustrate that a particular static control method has eliminated it. It should not be assumed that every ESD event detected results in damage to components or equipment problems. Additional testing will be needed to establish that connection.

## R4-5 Static Event Detectors

R4-5.1 Static event detectors (SED) are devices that are installed directly on products to detect the presence of an ESD event. They may be attached in proximity to an ESD-sensitive component, connected to the external device leads, or integrated into the device package. Typically they detect the current pulse of an ESD event through an antenna or direct connection to the device circuitry.

R4-5.2 SEDs can be useful in determining the occurrence of ESD events in operating production equipment. The SED has the ability to indicate ESD events of a known level, aiding in the design and performance verification of automated equipment. While costly analysis of failed devices can also provide this information, correlation to machine operations is usually difficult. An SED that can be monitored optically as it passes through operating equipment provides a convenient method to verify that automated equipment is not generating levels of static charge that result in ESD damage.

### R4-5.3 Types of SED Devices

R4-5.3.1 In some SED devices, the signal is amplified and processed to produce a reflectance change in the built-in Liquid Crystal Display (LCD). The SED is designed to trip at a predetermined threshold voltage, detecting ESD transients above the selected amplitude. Some devices can be reset magnetically or optically making them reusable.

R4-5.3.2 Other devices use the controllable ESD damage threshold of metal oxide semiconductor field effect transistors (MOSFET). The test methodology is to amplify an ESD transient to create sufficient energy to destroy the gate oxide. The device may be used until the specified ESD level is achieved, and then the SED fails. A similar device is based on the metal oxide semiconductor capacitor (MOSCAP). The current leakage through the device significantly increases if the ESD amplitude is sufficient to damage the MOS structure. Both of these types of SED must be removed from where they are installed and require additional instrumentation to determine their status.

R4-5.3.3 Another type of SED employs the magnetic fields from a current flow to affect a series of magneto-optic thin films. The magnetic field from the ESD current alters the film's magnetic state and affects the degree of polarization of visible light reflected from the film. Varying the distance between the film and the ESD current-carrying conductor indicates different thresholds. This SED can be read using a microscope equipped with a polarizing element and does not need to be removed from the circuitry to be read. It can be reset with a magnet.[15]

## R4-6 Conclusion

R4-6.1 There is little question that static charge problems continue to result in significant losses in high technology manufacturing. Increasingly, static control methods must be applied in the equipment that produces the product. It will be important to develop and utilize a range of diagnostic methods and measurement equipment for ESD in equipment.



15 Jackson, Tan, and Boehm, "Magneto Optical Static Event Detector," 1998 EOS/ESD Symposium, pp.233-244, ESD Association.

# SEMI E45-1101
# TEST METHOD FOR THE DETERMINATION OF INORGANIC CONTAMINATION FROM MINIENVIRONMENTS USING VAPOR PHASE DECOMPOSITION-TOTAL REFLECTION X-RAY SPECTROSCOPY (VPD/TXRF), VPD-ATOMIC ABSORPTION SPECTROSCOPY (VPD/AAS), OR VPD/INDUCTIVELY COUPLED PLASMA-MASS SPECTROMETRY (VPD/ICP-MS)

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the North American Regional Standards Committee on August 27, 2001. Initially available at www.semi.org September 2001; to be published November 2001. Originally published in 1995; previously published March 2001.

## 1 Purpose

1.1 This test method provides the analytical procedures to determine the level of inorganic contamination from a minienvironment.

## 2 Scope

2.1 This document relates to inorganic impurities, which includes metallic contaminants, whether they occur as atoms, molecules, or particles. The number of metals to be analyzed is restricted to the four elements sodium (Na), calcium (Ca), iron (Fe), and copper (Cu) in order to rapidly characterize minienvironments from a practicable point of view. While Na, Ca, and Fe represent one ensemble of highly detrimental impurities with respect to contamination from human sources (Na), the environment (Ca), or from equipment and corrosive effects (Fe), Cu is analyzed due to its increasing importance in semiconductor manufacturing. Additionally, they are easily analyzed with sufficiently low detection limits. It is up to the user of this test method to quantify additional elements. A list of suggested polished wafer surface metal contamination inappropriate to circuits and devices is shown in Table 1 (based on SEMI M1). The inorganic contamination on silicon wafer surfaces is collected by VPD.

2.2 To quantify Ca and Fe, VPD/TXRF is used due to its sufficiently low detection limits. Na and Cu are quantified by VPD/GFAAS or VPD/ICP-MS. All analytical methods are widely used for the characterization of surface cleanliness.

2.3 This measurement technique can also be used to check the influence of certain process steps on minienvironments.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

**Table 1 Suggested Polished Wafer Surface Metal Contamination Inappropriate to Circuits and Devices**

| *Element* | *Test Method* |
|---|---|
| Na | VPD/(AAS or ICP-MS) |
| Al | VPD/(AAS or ICP-MS) |
| K | VPD/(AAS or ICP-MS or TXRF) |
| Cr | VPD/(AAS or ICP-MS or TXRF) |
| Fe | VPD/(AAS or ICP-MS or TXRF) |
| Ni | VPD/(AAS or ICP-MS or TXRF) |
| Cu | VPD/(AAS or ICP-MS or TXRF) |
| Zn | VPD/(AAS or ICP-MS or TXRF) |
| Ca | VPD/(AAS or ICP-MS or TXRF) |

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI C28 — Specifications and Guidelines for Hydrofluoric Acid

SEMI C35 — Specifications and Guidelines for Nitric Acid

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI M1 — Specification for Polished Monocrystalline Silicon Wafers

3.2 *ISO Standards*[1]

ISO 9001 — Quality Systems—Model for Quality Assurance in Design, Development, Production, Installation, and Servicing

ISO 14644-1 — Cleanrooms and associated environments – Classification of air cleanliness

1 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Website: http://www.iso.ch

3.3 *DIN Standards*[2]

DIN 12650 Part 6 — Mechanical, physical and electrical laboratory apparatus; Piston operated volumetric apparatus; Gravimetric assessment of metrological reliability

NOTE 1: Unless otherwise indicated, all documents cited shall be the latest published versions.

## 4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 *GFAAS* — Graphite Furnace Atomic Absorption Spectroscopy

4.1.2 *ICP-MS* — Inductively Coupled Plasma – Mass Spectroscopy

4.1.3 *PFA* — Perfluoroalkoxy

4.1.4 *PTFE* — Polytetrafluoroethylene

4.1.5 *PVDF* — Polyvinylidene fluoride

4.1.6 *TXRF* — Total Reflection X-Ray Fluorescence Spectroscopy

4.1.7 *ULSI* — Ultra Large Scale Integration

4.1.8 *VPD* — Vapor Phase Decomposition

4.2 *Definitions*

4.2.1 *box* — a protective portable container for a cassette and/or substrates.

4.2.2 *cassette* — an open structure that holds one or more substrates (e.g., wafer, masks).

4.2.3 *DI water* — deionized water (specified with specific resistivity ≥ 18 MΩcm, cations: Na, Cu, Fe, Ca ≤ 0.2 µg/L).

4.2.4 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people.

4.2.5 *pod* — a box having a Standard Mechanical Interface (SMIF) (See SEMI E19).

4.2.6 *reference wafer* — a cleaned wafer (see Section 8.2).

4.2.7 *sampling wafer* — a cleaned wafer (see Section 8.2), which will be or was exposed to the minienvironment for a certain time.

4.2.8 *standard mechanical interface (SMIF)* — the interface plane between a pod and another minienvironment (see SEMI E19).

4.2.9 *vapor phase decomposition* — a method in which impurities on the surface are collected by the so-called VPD procedure, i.e., the non-volatile products formed by acid decomposition of the oxide at the wafer surface are collected by a droplet of collecting agent, usually ultra-pure hydrofluoric acid or other reagent or combination of reagents, and the droplet subsequently being analyzed by AAS or ICP-MS, or dried in a manner which gives the least environmental contamination, the residue from the droplet subsequently being analyzed by TXRF.

## 5 Interferences

5.1 For worst cases, preconditioning of wafers can result in different surface properties indicated by different sensitivities for contamination absorption.

5.2 Non-linearity effects of the TXRF detector are significant at higher concentration levels (> $10^{13}$ atoms/cm$^2$ under the detector area).

5.3 The collection efficiency of VPD depends on:

- the chemistry of the collecting solution
- the bonding of the metal impurities to the silicon surface
- the speed of the droplet, which is rolled over the wafer surface

5.3.1 Careful control of contamination and all other factors affecting the results such as solution concentrations, scanning methods and other procedures are necessary to obtain reproducible analytical results.

5.4 The measured TXRF intensity depends on the accuracy of the procedure to localize and to adjust to the sampled residue. It also depends on the distribution of different elements in and around the residue.

5.5 The detection of Fe or Ca using ICP-MS can be interfered with by background ions originated from the plasma unless some controlled measures are taken to minimize these interferences to acceptable levels.

## 6 Safety Precautions

6.1 Handling hydrofluoric acid is dangerous and shall be performed according to local regulations for laboratories. Operators shall be trained to deal with dangerous chemicals and vapors, especially hydrofluoric acid and HF vapor. Protective clothes and glasses must be worn when handling hydrofluoric acid.

## 7 Apparatus

7.1 The VPD treatment and contamination collection particularly, but also the handling and measurement of the specimen wafer is to be carried out in a specified

2 Available from Deutches Institut für Normung e.V., Beuth Verlag GmbH, Burggrafenstrasse 4-10, D-10787 Berlin, Germany. Website: http://www.din.de

and controlled ambient (e.g., ISO Class 4 (as defined in ISO 14644-1)).

7.2 The VPD and the advisable drying chamber(s) shall have opening(s) made of PVDF, PFA, PTFE or similar resistant and pure polymer materials that are not attacked by HF. The chamber(s) may contain one or more wafer stacks. After evacuation, the chamber shall be flushed with filtered $N_2$ until the complete drying of the microdroplet residue is achieved.

7.3 For the aliquots of standard stock and scanning solutions, validated micropipettes shall be used. DIN 12650 Part 6 provides an applicable validation procedure.

## 8 Procedure

These procedures show the determination of Na, Ca, Cu, and Fe on a silicon wafer surface with VPD/GFAAS, VPD/ICP-MS and VPD/TXRF. For achieving best detection limits, VPD/GFAAS and VPD/ICP-MS shall be used for NA and Cu whereas VPD/TXRF shall be used for Ca and Fe.

8.1 *Test Requirements* — The evaluation of the minienvironment and the analysis shall be carried out under appropriate clean conditions. Any potential for cross contamination shall be checked in advance. Possible contamination sources are:

- VPD preparation
- storage
- contaminated GFAAS or ICP-MS vessels
- environment
- measurement methods and collection efficiency of VPD
- handling

8.1.1 The capability of the analytical lab has to be checked carefully for compliance with Sections 8.2, 8.6, and 9.

8.2 *Surface Conditions and Cleaning Procedure* — Polished silicon wafers with the following specifications must be used:

- Specific resistivity = 1–100 Ωcm
- CZ crystal growth method
- Cleaned to leave a native oxide with hydrophilic surface conditions and with Na, Ca, Cu, and Fe concentrations lower than $1 \times 10^{10}$ atoms/cm$^2$

8.2.1 Wafer cleaning must be done less than ten minutes before any further processing. This restricted time limitation is necessary to ensure cross contamination avoidance.

8.3 *VPD Preparation* — The vessel for (opening > 25 cm$^2$) inside the VPD box is filled with 25 vol-% HF by mixing DI water with 50 vol-% VLSI-grade hydrofluoric acid (see SEMI C28) allowing hydrofluoric acid of between 25 to 50 wt % to be used. The wafers are then exposed to the hydrofluoric acid vapor. Allow wafers exposure to hydrofluoric acid vapor for 15 to 30 minutes, at which time the wafer should become hydrophobic due to oxide removal. The liquid reaction products are collected by rolling a DI water droplet over the whole wafer surface using up to 100 µL for advisable machine operation or an appropriate volume for manual operation. Any cross contamination is minimized by using DI water as solvent.

8.4 *Collection Procedure* — An automatic scanning procedure is preferable, but if the collection procedure is manual the following procedure should be used.

8.4.1 Use appropriate method to exclude the wafer edge.

8.4.2 A droplet of collecting agent, usually ultra-pure hydrofluoric acid or another reagent or a combination of reagents, is rolled over the whole surface of the wafer in a parallel pattern.

8.4.3 The same droplet is then moved over the whole surface, this time in a pattern orthogonal to the first.

8.4.4 Finally, the droplet is rolled in a spiral pattern from the wafer periphery to its center.

8.5 *Pre-analysis Procedure*

8.5.1 *GFAAS Analysis* — The wafer droplet is diluted to 500 µL.

8.5.2 *TXRF Analysis* — The droplet is evaporated on the wafer surface in a clean environment at room temperature under a nitrogen purge.

8.5.3 *ICP-MS Analysis* — The wafer droplet is diluted to 500 µL.

8.6 *Sodium and Copper Analysis by GFAAS*

8.6.1 *Calibration Standards* — 1 µg/L for Na.

8.6.2 The calibration frequency and procedures shall be in accordance with the requirements of the ISO 9001 quality system. The temperature program for the graphite furnace (dry, ash, atomize) is optimized for maximum sensitivity. Volatility (e.g., NaF) should be avoided by spiking the liquid samples with nitric acid (VLSI grade—see SEMI C35). Prior to analysis of the liquid sample, a three-point calibration of the element with an elemental standard is carried out (blank — 0.5 μg/L – 1 μg/L).

8.6.3 A detection limit for sodium and copper better than $5 \times 10^9$ atoms/cm$^2$ (approximately 0.1 μg/L for GFAAS analysis) is recommended.

8.6.4 The detection limit is defined by 3 • σ • R (σ = standard deviation, R = reciprocal slope of the calibration curve).

8.6.5 The surface concentration is calculated as follows:

$$C_s = C_l \times V \times NA \times 10^{-9} / (W \times A)$$

with:

$C_s$ (atoms/cm$^2$): surface concentration

$C_l$ (μg/L): analyzed concentration

V(mL): volume of diluted sample

NA = $6.023 \times 10^{23}$ mol$^{-1}$ : Avogadro number

A (cm$^2$): wafer surface area

W (g/mol): atomic weight of element (22.99 for sodium, 86.54 for copper)

8.7 *Sodium and Copper Analysis by ICP-MS*

8.7.1 *Calibration Standards* — 1 μg/L for both sodium and copper.

8.7.2 A detection limit for sodium and copper better than $5 \times 10^9$ atoms/cm$^2$ (e.g., for 200–300 mm wafers) is recommended.

8.7.3 The detection limit is defined by 3 • σ • R (σ = standard deviation, R = reciprocal slope of the calibration curve).

8.7.4 The surface concentration is calculated as follows:

$$C_s = C_l \times V \times NA \times 10^{-9} / (W \times A)$$

with:

$C_s$ (atoms/cm$^2$): surface concentration

$C_l$ (μg/L): analyzed concentration

V(ml): volume of diluted sample

NA = $6.023 \times 10^{23}$ /mol : Avogadro number

A (cm$^2$): wafer surface area

W (g/mol): atomic weight of element (22.99 for Na, 86.54 for copper)

8.8 *Calcium and Iron Analysis by TXRF*

8.8.1 *Calibration Standards* — The ISO 9001 quality system shall be applied to the calibration. The instrument is calibrated by analyzing the calibration wafer. The calibration wafer is prepared by dropping a solution of metal standard (e.g., Ni or Co) on a clean wafer surface. The volume of the droplet is the same as used for VPD preparation (up to 100 μL), and the resulting surface concentration must be in the lower $10^{11}$ atoms/cm$^2$ range. The droplet is then evaporated on the wafer surface at room temperature under nitrogen purge until the liquid matrix is removed. Its residue is analyzed by TXRF. The detection limit is defined by 3 • σ • R (σ = standard deviation, R = reciprocal slope of the calibration curve). Note that the droplet area must be smaller than the spot area of the detector.

8.8.2 Reproducibility shall be first established following the procedure below.

8.8.3 Define a grid of 3 × 3 measurement points with an inter distance of 3 mm. The reside position, found by optical inspection, shall be located at the center of the matrix.

8.8.4 Determine the intensity by short analyses of each of the nine measurement locations. The analysis area is at maximum intensity for the standard element of the calibration wafer.

8.8.4.1 Calibration shall be checked weekly and after each equipment service (e.g., after an exchange of filament, anode, or repair of anode) with the same calibration wafer.

8.8.4.2 The surface concentration is calculated as follows:

$$C_s = RSF_m \times (C_0/I_0) \times I$$

with:

$C_s$ (atoms/cm$^2$): surface concentration of analyzed metal M

I (counts/s): analyzed intensity of metal M

$C_0$ (atoms/cm$^2$): surface concentration of standard metal S (Ni or Co) on calibration wafer

$I_0$ (counts/s): analyzed intensity of standard metal S on calibration wafer

$RSF_m$: relative sensitivity factor of investigated metal M to standard metal S

8.8.4.3 The constants $RSF_m$ are implemented in the software of the TXRF equipment.

8.9 *Sampling Procedure* — If the average elemental concentration for the sampling wafers is higher than the average elemental concentration plus three standard deviations for the analyzed reference wafers, then the sampled minienvironment is considered to cause significant contamination.

8.9.1 *Minienvironment Exposure* — The following exposure time for sampling specific minienvironments shall be used:

Minienvironments used to store wafers: 168 h

Minienvironments as an interface to process tools: 24 h

8.9.2 *Minienvironments for Storing Wafers* — Fill the minienvironment with six wafers. Measure wafers by VPD/GFAAS or VPD/ICP-MS in front, back, and center slots. Use the adjacent wafers for VPD/TXRF.

8.9.3 *Minienvironments for Introducing Wafers to Process Tools* — Introduce six wafers into the minienvironment. Measure three wafers with VPD/GFAAS or VPD/ICP-MS, one in the center position and two at the edge positions opposite to each other. Use the adjacent wafers for VPD/TXRF. In the case of single wafer minienvironments, wafers are processed sequentially. To ensure that no cross contamination is introduced from conditions prevailing in storing, transportation, or any of the handling processes, precautions must be adhered to at all times.

## 9 Results

9.1 The investigated minienvironment must be described in detail (e.g., construction, materials, history, process, cleaning procedures, storage conditions). All surface concentrations must be fully reported.

9.2 The number of tested sampling and reference wafers, average elemental concentration, and standard deviation of the reference wafers, slot positions, position in the minienvironment, and number of repeated experiments (if applicable) must be documented.

9.3 All equipment, tools, and chemicals used must be specified within the report.

## 10 Related Documents

10.1 *SEMI Standards*

SEMI C30 — Specifications and Guidelines for Hydrogen Peroxide

NOTE 2: Unless otherwise indicated, all documents cited shall be the latest published versions.

10.2 *Other Documents*

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# SEMI E46-0301
# TEST METHOD FOR THE DETERMINATION OF ORGANIC CONTAMINATION FROM MINIENVIRONMENTS USING ION MOBILITY SPECTROMETRY (IMS)

This test method was technically approved by the Global Metrics Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on December 20, 2000. Initially available at www.semi.org February 2001; to be published March 2001. Originally published in 1995.

## 1 Purpose

1.1 The purpose of this test method is to provide an analytical procedure—Ion Mobility Spectrometry (IMS)—for the determination of organic contamination from minienvironments which has the capability of testing their construction material.

## 2 Scope

2.1 Silicon wafers passed through or stored in minienvironments may be affected by organic contamination originating from construction materials. Knowledge of this contamination assists the decision about the application of minienvironments in semiconductor manufacturing.

2.2 Ion Mobility Spectrometry was chosen as the method to determine this contamination because it provides an easy, widely applicable, fast and sensitive way to measure organic contamination on surfaces.

2.3 Furthermore, IMS provides the possibility of checking the contaminating effects of processing, chemical carryover, and the characterization of future polymeric materials for use in semiconductor technology.

2.4 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 3 Referenced Documents

3.1 *SEMI Documents*

*SEMI E19* — Standard Mechanical Interface (SMIF)

SEMI Minienvironment Terminology Workshop Proceedings, April 2, 1993

## 4 Terminology

4.1 Box/Cassette/Minienvironment/Pod

4.2 *DOP* — Dioctylphthalate

4.3 *Headspace* — The volume above the sample containing the gas to be analyzed

4.4 *HPB* — Hexaphenylbenzene

4.5 *IMS* — Ion Mobility Spectrometry

4.6 *IMS/MS* — Ion Mobility Spectrometry/Mass Spectrometry

4.7 *NS* — Standardized Ground Joint

4.8 *SMIF (Standard Mechanical Interface)* — The interface plane between a pod and another minienvironment as per SEMI E19.

4.9 *PFA* — Polyfluoroalkoxy

4.10 *PP* — Polypropylene

## 5 Summary of Method

5.1 This test method defines a fast, sensitive technique for the determination of organic contamination from minienvironments. The contamination is measured directly from the silicon surface. Three important aspects are covered:

a. Contamination due to the minienvironment alone,

b. Contamination from the use of minienvironments for wafer processing, and

c. Contamination from future materials to be used in semiconductor technology.

5.2 Silicon wafers are either placed in the minienvironment or used for headspace sampling experiments. The sample is heated and the target compound is either desorbed or outgassed. These compounds are swept by the carrier gas into the Ion Molecule Reactor. Here the molecules are chemically ionized under atmospheric pressure. The target ions are separated in a drift cell by electrophoreses in the gaseous state and detected by an electrometer. Additionally, a quadrupole mass spectrometer could be used as a second detector. The result is a quantitative value for the total amount of organic surface contamination.

## 6 Interferences

6.1 To adequately measure organic contaminants from minienvironments, an extremely sensitive method for analyzing volatiles is required. At this time, the only analytical method meeting these requirements is IMS. The absolute determination of organic contamination by the IMS method is still limited, especially in the presence of many analytes, but this proposed test method permits the comparison of quantitative results from different laboratories.

## 7 Apparatus

7.1 *Minimum Requirements for the Ion Mobility Spectrometer* — For the successful performance of the experiments using the IMS instrument, the following requirements are essential:

— minimum length of the drift cell: 4 cm

— sample inlet has to be lockable (no sniffing devices)

— sample desorption oven must have a programmable temperature control

— the electronics must guarantee a linear amplification of the observed signal

— intensity over at least five orders of magnitude

— documentation of all single measurement results.

7.2 *Measuring Parameters* — For measurements with the ion mobility spectrometer, the following parameters have to be used:

temperature of the desorption furnace: 200°C*

temperature of the drift cell and IMS detector: 205°C*

maximum dwell time or channel length corresponding to minimum time resolution: 80 µs**

measuring time per spectrum: 40 ms*

(for 200 V/cm and 10 cm length of drift cell)

gatewidth: 200 µs**

number of scans: 2000**

drift gas and carrier gas: zero grade (synthetic) air*

- approx. 10 ppm $H_2O$*
- max 0.1 ppmv total hydrocarbons*

carrier gas flow: 100 mL/min* (for a diameter of 3.9 mm)

drift gas flow: 500 mL/min** (for a diameter of 4.25 cm)

* specified; ** suggested

## 8 Reagents

8.1 The chemicals must be of the described quality or better and supplied with a certificate of analysis.

Benzene: ultrapure quality for trace residue analysis. Minimum quality: pro analysi.

- content of benzene: min. 99.8%
- content of water: max. 0.02%
- nonvolatile residue: max. 0.0005%

Ethanol: ultrapure quality for trace residue analysis. Absolute.

- content of ethanol: min. 99.8%
- content of water: max. 0.1%
- nonvolatile residue: max. 0.0005%

DOP: normal pure quality.

- content of DOP: better than 96%

HPB: normal pure quality.

- content of HPB: better than 96%

## 9 Safety Precautions

9.1 All preparation and measurement work has to be done according to local regulations for laboratories.

## 10 Procedure

10.1 *Preparation Tools and Auxiliaries* — The following equipment is needed for the preparation of polymer headspace substrates:

- protective eye wear
- 1 fume cupboard
- 1 butane burner
- 2 pairs of crucible tongs made of stainless steel
- scalpel with changeable blades
- 4 pairs of cross tweezers with tips made of steel
- 1 metal vernier calliper
- Si-wafer-chips: formate 20 × 10 $mm^2$
- watch glass
- weighing bottle with lid, both made of glass

    inner diameter: 80 mm

    height: 30 mm

ground joint NS80

- aluminum foil
- 2 metal saws
- table vice
- finely toothed metal file
- steel ruler (30 cm)

10.2 *Preconditioning Procedure (Thermal Decontamination)* — In order to assure that all environmental influences are eliminated, all thermal decontamination procedures described in the following have to take place immediately before the appropriate measurements or experiments are performed.

10.2.1 *Preconditioning of Aluminum Foil* — Two cross tweezers are flamed with a butane torch in the fume cupboard (1 min., red heat). A piece of aluminum foil (20 × 30 $cm^2$) is folded multiply and, by using tweezers, is carefully heated in the flame until fully converted. After cooling down, the foil is stored on a fire resistant surface (ceramics preferred).

10.2.2 *Preconditioning of Weighing Bottles* — The jaws of the crucible tongs are heated in the butane torch until they are red hot for two minutes. After a short cooling period (15 s), the bottom of the weighing bottle is picked up. For several times, the inner and the outer surfaces of the glass are heated alternately in the torch (2 minutes for each run). After approximately 30 s of cooling down - held in air by the tongs - the flamed weighing bottle is put down on the preconditioned aluminum foil. The tongs are allowed to cool for 15 s, then the lid is prepared in the same way. After 10 minutes of cooling, the lid can be placed on the weighing bottle.

10.2.3 *Preconditioning of Watch Glass* — The watch glass is picked up with preconditioned cross tweezers and carefully heated in the butane torch for 30 s (without deformation by melting).

10.2.3.1 Simultaneously, the tips of a second pair of cross tweezers are heated to red heat. After 30 s, the watch glass is transferred by these tweezers, carefully heated for another 30 s to red heat (total heating time, 1 min), and placed on the preconditioned aluminum foil. After a cooling period of 5 minutes, the watch glass is picked up with a clean pair of preconditioned cross tweezers and placed inside the weighing bottle.

10.2.4 *Preconditioning of Si-chips* — Wafers, as received, are cut into chips of 20 × 10 $mm^2$ in size. The use of cotton gloves is recommended to avoid organic contamination through fingerprints. Then one Si-chip is picked up with a pair of cross tweezers and heated to red hot in a butane torch (30 s). Simultaneously, the tips of a second pair of cross tweezers are heated to red hot. After 30 s, the Si-chip is transferred to these tweezers and heated for another 30 s to red heat (total heating time, 1 min). After cooling, the Si-chip is transferred into the preconditioned weighing bottle. The weighing bottle must be opened and closed only with the thermally decontaminated crucible tongs.

10.2.4.1 The lid must be placed only on the preconditioned aluminum foil. Five more Si-chips are preconditioned as described above and placed into the weighing bottle. The six Si-chips must not overlap or touch one another. The Si-chips should be placed on the preconditioned watch glass.

10.2.5 *Preparation of Polymer Material* — The table top vice is mounted on a clean work-bench. The cross tweezers, the blade of a metal saw, the scalpel, the metal vernier calliper (within the measuring range), the steel ruler (in the range of 0 to 3 cm), and the finely toothed metal file are thermally decontaminated. Having decontaminated the metal saw, an area of approximately 50 × 50 $mm^2$ is sawed off the polymeric material and fixed with the clean cross tweezers. This piece of polymer material is then clamped vertically between the jaws of the vice. An area 12 × 20 $mm^2$ is carefully marked with the scalpel and cut out with the metal saw. Before total separation, the polymer sample is clamped with cross tweezers while the jaws of the vice are covered with the decontaminated aluminum foil. After clamping the polymer sample between the jaws of the vice, all sides of the polymer sample are carefully filed to length wit ha metal file (size control with metal vernier caliper). Then the polymer sample is placed on a clean watch glass by cleaned tweezers. The watch glass is positioned on the thermally cleaned aluminum foil. Both parts are stored inside the preconditioned weighing bottle which is carefully closed with its lid. The weighing bottle, within which the Si-chips are stored, is wrapped in preconditioned aluminum foil for storage and transportation.

10.3 *IMS Measurements Procedure*

10.3.1 *Blank Measurement* — The background signal level (noise) of the equipment must be defined by measuring the clean and stabilized IMS-equipment, without sample, three times for each polarity.

10.3.2 *Reference Measurement* — All manipulations etc. with the reference chemicals (Hexaphenylbenzene and Dioctylphthalate) have to take place entirely in PFA containers etc. Following equipment is needed:

2 narrow necked flasks (PFA), 250 mL

2 weighing boats (PFA)

! ! low weight, diameter smaller than diameter of narrow necked flask! !

2 pipettes (glass), 100 mL

1 micro dropper with changeable tips of 2 µL (may be PP)

1 micro spatula (metal)

1 micro balance, measuring range $10^{-6}$ g to 1 g at least

10.3.2.1 Preparation of the reference measurement with HPB:

10.3.2.1.1 Before the HPB is weighed, the PFA-bottle and the weighing boat have to be cleaned. For this the weighing boat and 10 mL benzene are given into the bottle. The bottle is closed and shaken well for approx. 1 minute. The benzene is discarded. This procedure is repeated four times. After the last cleaning the empty open bottle and the weighing boat, placed on a decontaminated aluminum foil (see Section 10.2.1). are allowed to dry at room temperature in a fume cupboard for ten minutes. Then the bottle is closed. The weighing boat is placed onto the micro balance by thermally decontaminated cross tweezers. Approx. 5 mg of HPB are weighed into the weighing boat by use of a thermally decontaminated micro spatula. The weight is recorded exactly for the later calculation. The weighing boat is placed into the PFA bottle by the cross tweezers.

10.3.2.1.2 The volume of the benzene is measured using a 100 mL-pipette. Before use, the pipette has to be washed 5 times using 10 mL benzene each time. The 100 mL benzene are filled into the PFA flask, which is closed immediately.

10.3.2.1.3 First the bottle, now containing HPB and benzene, is shaken well for three minutes. Often this is not sufficient for a complete dissolution of the HPB (visible inspection). To assure complete dissolution, the PFA flask is placed into an ultrasonic bath for 5 minutes (not longer, because solution may get hot). Two minutes before the end of that time the preparation of the silicon chip is started. The piece of silicon is heated to red heat for one minute, placed on the thermally decontaminated aluminum foil and given 5 minutes to cool. When the treatment in the ultrasonic bath is finished, the PFA flask is shaken for three minutes again, then given 2 minutes for just standing.

10.3.2.1.4 The bottle is opened. By the micro dropper 2 µL are taken from near the surface (tip not more than 1 mm under surface of liquid). The 2 µL are spread onto the silicon chip in such a way that the liquid on the chip covers the smallest possible area. Care is to be taken to prevent large spreading or even dropping off the liquid (e.g., the Si chip has to be positioned flat). The liquid is given 5 minutes to evaporate (room temperature, no extensive blowing of air). Then the measurement of the HPB reference can be started.

10.3.2.1.5 Before each following HPB measurement the flask again has to be shaken 3 minutes, 5 minutes ultrasonic bath, shaking 3 minutes, allow two minutes of resting. The solution of the HPB in benzene must not be kept longer than 10 days.

10.3.2.1.6 The reproducibility of the integral value (see calculation) achieved by this procedure is better than 4%. Sample measurements shall be performed only, if the reference measurement has provided a reproducibility equal to or better than 10%.

NOTE 1: Hexaphenylbenzene has been chosen as a reference compound because its signal is well-defined and its mobility value is well separated from the peaks of nearly all other relevant organic contaminants. It provides positive ions only. A different reference, Dioctylphthalate, is needed for negative ions.

10.3.2.1.7 DOP-reference samples: All the same as HPB, except replacing the benzene by ethanol. The DOP is weighed using a micro dropper (not spatula).

10.3.2.1.8 The mobility spectrum of dioctylphthalate is also well separated but there are several peaks due to thermal decomposition (phthalic anhydride etc.). This compound is a frequently used plasticizer and therefore one of the most critical polymer additives.

10.3.3 *Measurement of the Headspace Samples* — Positive and negative ions are detected successively in two separate runs. At least two independent measurements are carried out for each polarity. Every measurement to be saved consists of 2000 single scans and is then repeated. Hence, an automated measurement is required.

10.3.3.1 The silicon chip is placed in the furnace of the IMS using thermally decontaminated cross tweezers. The measurement of the drift time spectrum (positive or negative polarity) has to be started immediately after loading the desorption furnace with the sample (time delay between sample introduction and starting of the measurement: 15 s).

10.3.4 *Termination of the Measurement* — The measurement is terminated when the signal intensity has decreased to about 10% above the noise of the blank measurement spectrum. If this point is not reached after two hours, the measurement should be terminated; in this case, the investigated sample does not show suitable material properties.

10.4 *Headspace Sampling in Minienvironments* — The crucible tongs are preconditioned as described in Section 10.2, and the preconditioned aluminum foil is placed beside the minienvironment that is to be examined. After opening the minienvironment, the lid of the weighing bottle is picked up with the crucible tongs and carefully placed on the aluminum foil. Both the weighing bottle (holding the Si-chips) and its lid are separately put inside the minienvironment. Then the minienvironment is closed and kept closed for a defined period of time. For this test method, one week (168 h) is defined. After expiry of the storage time, the weighing bottle is closed with its lid and removed from the minienvironment.

10.4.1 The same procedure applies to standard wafer boxes or to SMIF and similar boxes.

10.5 *Headspace Sampling of Polymer Material at Different Temperatures* — The prepared polymer material inside the wrapped weighing bottle (see Section 10.2.5) is stored:

- either under clean laboratory conditions at room temperature for a defined period of time
- or in a suitable oven at a temperature of 70°C or 120°C for exactly 1 hour followed by a cooling period of 1 hour.

10.5.1 The wrapped weighing bottle is handled with a pair of crucible tongs only.

10.6 *Testing Requirements* (check for device overload during measurement)

10.6.1 *Positive Ions: Water Cluster Signal Intensity* — The water cluster signal intensity must not decrease by more than 10% of the blank spectra intensity during measurement time; otherwise, the ion molecule reactor has been overloaded. If this is the case, the polymer sample is not likely to be suitable for use in semiconductor processing because of unacceptable properties.

10.6.2 *Negative Ions: Oxygen Cluster Signal Intensity* — The same procedure as that in Section 10.6.1 must be performed for negative ions; in this case, the oxygen cluster signal intensity must not decrease by more than 20%.

## 11 Calculation

11.1 *Description of Mobility Spectra Evaluation* — The signal intensities of the detected sample contaminants are integrated over a specific interval for both polarities. The background signal intensity is integrated, outside the specific measurement interval, with preference to spectral region prior to the peaks of the reactant ions. The total background intensity (integration of the relevant background signal) is subtracted from the integrated contamination intensity (background correction). The mean value of the contamination signal from the blank measurement (Section 10.3.1) spectra is subtracted accordingly. This leads to individual contamination values from each sample spectrum.

11.2 Calculation of reduced mobility:

$K = E^{-1}\, l_d / t_d$ and

$K_0 = K\,(p/p_0)\,(T_0/T)$

$K$ : ion mobility ($cm^2/Vs$)

$K_0$ : reduced ion mobility ($cm^2/Vs$)

$p$ : pressure

$p_0$ : standard pressure

$T$ : temperature

$T_0$ : standard temperature (273.15K)

$l_d$ : drift length (cm)

$t_d$ : drift time (s)

$E$ : electric field strength (V/cm)

$K$ : Kelvin

11.2.1 Table 1 shows the specified integration range; all reduced mobility values are given in units of $cm^2/Vs$.

11.2.2 The resulting integrals for each spectrum are summed up for the whole desorption time. This value is compared to the appropriate value of the reference sample (HPB or DOP).

11.2.3 This procedure ensures the comparison of the evaluated sample contamination values between different laboratories and measurement equipments.

## 12 Related Documents

12.1 K. Budde, “Application of Ion Mobility Spectrometry to Semiconductor Technology,” Proceedings of the Satellite Symposium to ESSDERC 89 (Berlin) of the Electrochemical Society (the Electrochemical Society Pennington, 1990) PV 90-11, p.215.

12.2 K. Budde, W. J. Holzapfel, “Measurement of Organic Contamination from Silicon Surfaces,” Proceedings, 38th Meeting, Institute of Environmental Sciences, 3.-8.5.1992, Nashville, TN, p.483.

12.3 K. Budde, W. J. Holzapfel, “Detection of Volatile Organic Surface Contaminations Arising from Wafer Boxes and Cleaning Processes,” Proceedings of the First International Symposium on Semiconductor Wafer Bonding, (the Electrochemical Society Pennington, 1992) PV 92-7, p. 271.

12.4 Proposal: SEMATECH Test Method for Determining Outgassing Products from Semiconductor Product Carriers.

12.5 S.N. Ketkar, S.M. Penn, and W.L. Fite, “Influence of Coexisting Analytes in Atmospheric Pressure Ionization Mass Spectrometry,” Anal. Chem. 63, (1991) 924.

12.6 R.E. Clement, K.W.M. Siu, and H.H. Hill Jr., "Instrumentation for Trace Organic Monitoring," Lewin Publishers, Boca Raton 1991.

**Table 1 Integration Range for the Evaluation of Ion Mobility Spectra**

| *Polarity of Target Ions* | *Sample* | *Background* | *Signal Range (sample)* |
|---|---|---|---|
| positive | HPB | 42.10–5.81 | 0.86–0.77 |
| negative | DOP | 37.30–7.35 | 1.99–1.63 |
| positive | Sample | 42.10–5.81 | 2.24–0.84 |
| negative | Sample | 37.30–7.35 | 2.30–0.91 |

# SEMI E47-0301
# SPECIFICATION FOR 150 mm/200 mm POD HANDLES

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the European Equipment Automation Committee. Current edition approved by the European Regional Standards Committee on October 26, 2000. Initially available at www.semi.org January 2001; to be published March 2001. Originally published in 1995; previously published October 2000.

## 1 Purpose

1.1 This specification provides a unified form and location for pod handles to enable automatic pod handling.

## 2 Scope

2.1 This specification defines the dimensions and location of handles on 150 mm/200 mm pod. These provide automatic handling and take into consideration manual handling. The design of individual manual handles is open to be accomplished within the dimensional limitations of the standard.

2.2 This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

## 3 Limitations

3.1 This specification applies only to automatic handling of the pod with a SMIF interface in the horizontal plane (see limitations of SEMI E19.3 and E19.4). Dimensional restrictions for manual handling are given in SEMI E15 and SEMI T4.

## 4 Referenced Standards

4.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

SEMI E19.3 — 150 mm Standard Mechanical Interface (SMIF)

SEMI E19.4 — 200 mm Standard Mechanical Interface (SMIF)

SEMI E47.1 — Provisional Mechanical Specification for Boxes and Pods Used to Transport and Store 300 mm Wafers

SEMI T4 — Specification for 150 mm and 200 mm Pod Identification Dimensions

NOTE 1: As listed or revised, all documents cited shall be the latest publications of adopted standards.

## 5 Terminology

5.1 *standard mechanical interface (SMIF)* — the interface plane between a pod and another minienvironment per SEMI E19.

5.2 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19.

5.3 *box* — a protective portable container for a cassette and/or substrate(s).

5.4 *cassette* — an open structure that holds one or more substrates (wafer, masks, etc.).

5.5 *handle of a pod* — a mechanical aid designed for automatic handling of a pod, which may also be used for manual handling.

5.6 *handling area* — minimum free space around the pod for automatic handling.

5.7 *handling of a pod* — automatic and manual movement and/or placement of a pod.

5.8 *orientation notch* — notch located at the pod handles to allow sensing the orientation of the pod. See Figure 1.

5.9 *position notch* — notch located at the center lines of the pod handles to allow positioning. See Figure 1 (PN1 to PN4).

## 6 Requirements

6.1 Handling Dimensions: the handling dimensions for 150 mm and 200 mm pods shall be per Table 1 (see Figure 1 for dimensional locations).

6.2 A8 is given as a minimum and can be extended up to A1.

6.3 Number of handles shall be:

6.3.1 four (H1–H4 in Figure 2) or

6.3.2 two (H1 and H3) in Figure 2.

6.4 The handling area is defined by A5 (which is in reference to A1) and by B2. B1 is the minimum distance between the interface plane and the nearest extension of the handle.

6.5 The orientation possibilities of the pod are given in Figure 2 and Table 2.

6.6 An optional handle to be placed at the top of the pod is specified in SEMI E47.1 (Section 6.9, Figure 12, and Table 1). If used for 150 mm or 200 mm pods, this "top robotic handling flange" has to meet the required dimensions as specified in SEMI E47.1 (see Figure 12 of SEMI E47.1). Its center is to be placed above the center of the cassette in the pod with the two orientation notches at the side where the cassette is accessed to remove wafers. The orientation possibilities of the pod are then the same as described in Section 6.5 above and Table 2.

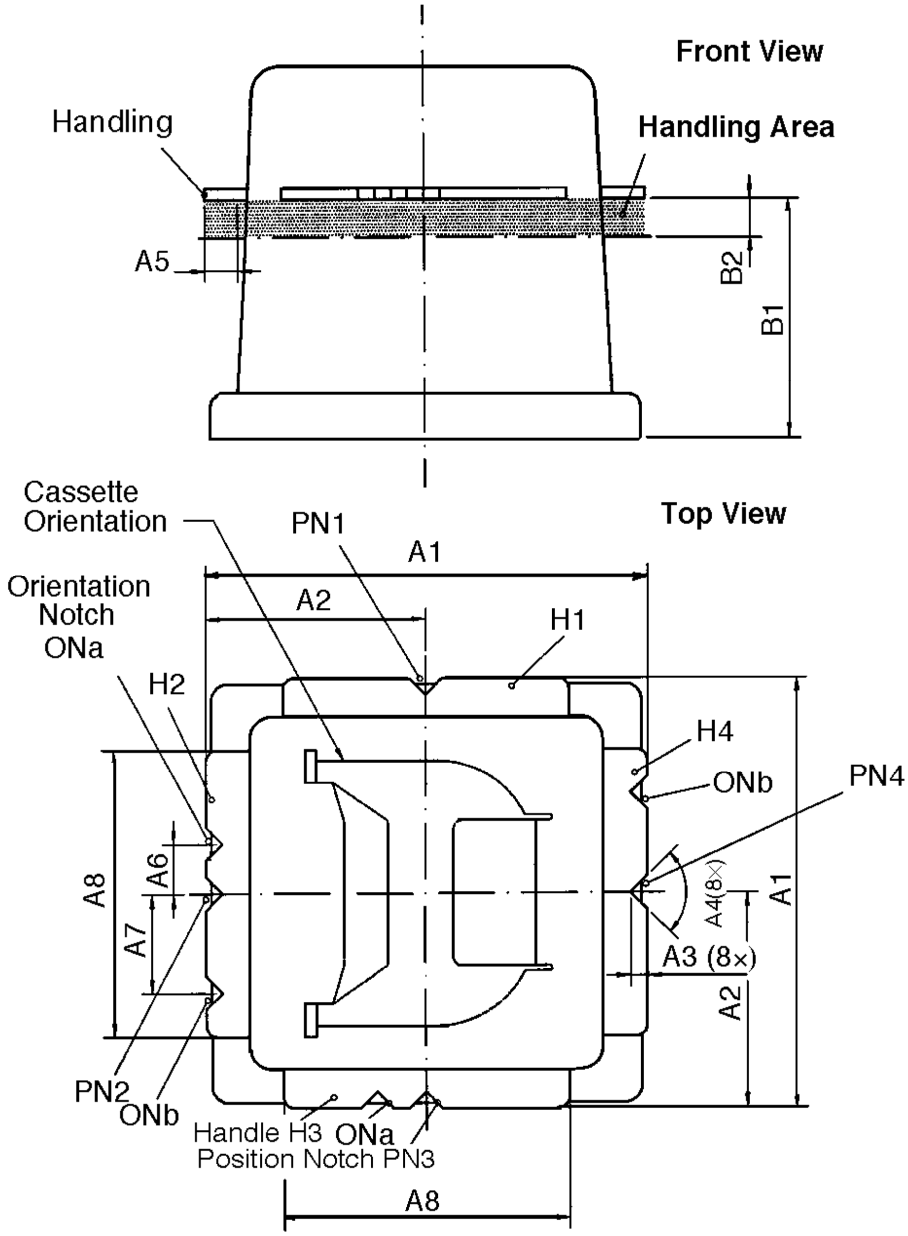


**Figure 1**
**Pod Handling Terminology and Dimensions**

**Table 1**

| | | *Handling Dimensions for 150 mm (6 in.) Pod* | *Handling Dimensions for 200 mm (8 in.) Pod* |
|---|---|---|---|
| Handle: | A1 | 215.0 mm ± 0.5 mm (8.464" ± 0.019") | 305.0 mm ± 0.5 mm (12.008" ± 0.019") |
| | A2 | 107.50 mm ± 0.25 mm (4.232" ± 0.01") | 152.50 mm ± 0.25 mm (6.004" ± 0.01") |
| | A3 | 6.0 mm ± 0.2 mm (0.236" ± 0.008") | 5.65 mm ± 0.2 mm (0.222" ± 0.008") |
| | A4 | 90° ± 0.2° | 90° ± 0.2° (90° ± 0.2°) |
| | A5 | 14 mm min. (0.551" min.) | 20 mm min. (0.787" min.) |
| | A6 | 30 mm ± 0.2 mm (1.181" ± 0.008") | 30.0 mm ± 0.2 mm (1.181" ± 0.008") |
| | A7 | 50 mm ± 0.2 mm (1.969" ± 0.008") | 50.0 mm ± 0.2 mm (1.969" ± 0.008") |
| | A8 | 148 mm min., 215 mm max. (A1)<br>(5.827" min., 8.464" max.) | 148 mm min., 305 mm max. (A1)<br>(5.827" min., 12.008" max.) |
| Handle Height: | B1 | 158 mm ± 1.0 mm (6.220" ± 0.039") | 150.4 mm ± 1.0 mm (5.921" ± 0.039") |
| Handling Area: | B2 | 30 mm min. (1.181" min.) | 30 mm min. (1.181" min.) |

**Table 2**

| *Orientation #* | *Orientation Notch* |
|---|---|
| 1 | void |
| 2 | ON a |
| 3 | ON b |
| 4 | ON a+b |

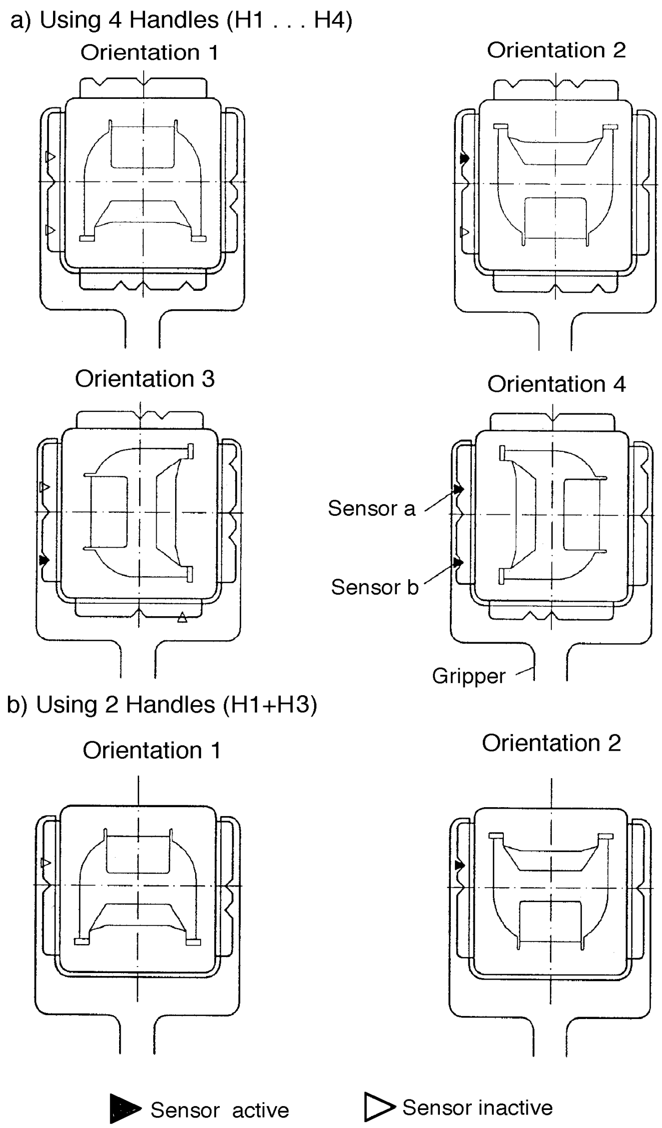


**Figure 2**
**Orientation Possibilities**

# SEMI E47.1-0305
# PROVISIONAL MECHANICAL SPECIFICATION FOR FOUPS USED TO TRANSPORT AND STORE 300 mm WAFERS

This specification was technically approved by the Global Physical Interfaces & Carriers Committee and is the direct responsibility of the North American Physical Interfaces & Carriers Committee. Current edition approved by the North American Regional Standards Committee on December 10, 2004. Initially available at www.semi.org February 2005; to be published March 2005. Originally published in 1997; previously published November 2004.

## 1 Purpose

1.1 This standard partially specifies the FOUPs used to transport and store 300 mm wafers in an IC manufacturing facility.

## 2 Scope

2.1 This standard is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and interchange-ability at all mechanical interfaces. Most of the requirements given in this specification are in the form of maximum or minimum dimensions with very few required surfaces. Only the physical interfaces (other than the door mechanism and kinematic couplings) for FOUPs are specified; no materials requirements or micro-contamination limits are given. The enclosure specified in this standard can be a sealed minienvironment, but it could also just be a box with well-defined interfaces.

2.2 The FOUP has the following components and sub-components:

Key:

- • Required feature
- ◊ Optional feature

- • top
- • top handling flange
- • center hole on top handling flange
- ◊ 3 kinematic grooves on top handling flange (optional)
- • interior
  - • cassette (with supports for 13 or 25 wafers)
  - • wafer capture mechanism
  - • 2 end effector exclusion zones
- • sides
  - ◊ 2 side fork-lift flanges (optional)
  - ◊ ergonomic manual handles (optional)
- • door
- • holes for latch keys that lock the door to the FIMS interface when the door is unlatched from the FOUP
- • holes for registration pins
- • door sensing pads
- • bottom
  - • 4 bottom conveyor rails (with the bottom of the front seal zone acting as the fourth rail and the rear rail optional)

- 2 fork-lift pin holes
- 5 carrier sensing pads
- center retaining feature
- front retaining feature
- 4 info pads
- 2 advancing FOUP sensing pads
- 3 features that mate with kinematic coupling pins and provide a 10 mm lead in

◊ 3 features that mate with kinematic coupling pins and provide a 15 mm lead in (optional)

◊ front conveyor surface

2.3 This standard is provisional because of concerns about the kinematic coupling pins causing excessive wear on carriers and the usefulness of the robotic handling flanges and conveyor rails. Once FOUP testing is done, this standard should be modified and upgraded from provisional status.

**NOTICE:** This standard does not purport to address safety issues, if any, associated with its use. It is the responsibility of the users of this standard to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI E1.9 — Mechanical Specification for Cassettes Used to Transport and Store 300 mm Wafers

SEMI E15 — Specification for Tool Load Port

SEMI E15.1 — Specification for 300 mm Tool Load Port

SEMI E19 — Standard Mechanical Interface (SMIF)

SEMI E47 — Specification for 150 mm/200 mm Pod Handles

SEMI E57 — Mechanical Specification for Kinematic Couplings Used to Align and Support 300 mm Wafer Carriers

SEMI E62 — Provisional Specification for 300 mm Front-Opening Interface Mechanical Standard (FIMS)

SEMI S8 — Safety Guidelines for Ergonomics Engineering of Semiconductor Manufacturing Equipment

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

## 4 Terminology

4.1 *Definitions*

4.1.1 *bilateral datum plane* — a vertical plane that bi-sects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.1.2 *box* — a protective portable container for a cassette and/or substrate(s).

4.1.3 *carrier capacity* — the number of substrates that a carrier holds (as defined in SEMI E1.9).

4.1.4 *cassette* — an open structure that holds one or more substrates.

4.1.5 *facial datum plane* — a vertical plane that bisects the wafers and that is parallel to the front side of the carrier (where wafers are removed or inserted). On tool load ports, it is also parallel to the load face plane specified in SEMI E15 on the side of the tool where the carrier is loaded and unloaded (as defined in SEMI E57).

4.1.6 *front-opening unified pod (FOUP)* — a box (that complies with SEMI E47.1) with a non-removable cassette (so that its interior complies with SEMI E1.9) and with a front-opening interface (that mates with a FIMS port that complies with SEMI E62).

4.1.7 *horizontal datum plane* — a horizontal plane from which projects the kinematic-coupling pins on which the carrier sits. On tool load ports, it is at the load height specified in SEMI E15 and might not be physically realized as a surface (as defined in SEMI E57).

4.1.8 *minienvironment* — a localized environment created by an enclosure to isolate the product from contamination and people.

4.1.9 *nominal wafer center line* — the line that is defined by the intersection of the two vertical datum planes (facial and bilateral) and that passes through the nominal centers of the seated wafers (which must be horizontal when the carrier is placed on the coupling) (as defined in SEMI E57).

4.1.10 *pod* — a box having a Standard Mechanical Interface (SMIF) per SEMI E19.

4.1.11 *robotic handling flanges* — horizontal projec-tions on the top of the FOUP for lifting and rotating the FOUP.

4.1.12 *wafer carrier* — any cassette, box, pod, or boat that contains wafers (as defined in SEMI E15).

## 5 Ordering Information

5.1 *Intended Use* — This standard is intended to specify 300 mm FOUPs over a reasonable lifetime of use, not just those in new condition. For this reason, the purchaser needs to specify a time period and the number and type of uses to which the FOUPs will be put. It is under these conditions that the FOUPs must remain in compliance with the requirements listed in §6.

5.2 *Temperature Ranges* — The purchaser of 300 mm FOUPs needs to specify two sets of temperatures to which the FOUPs might be exposed. An operating temperature range is the set of environmental temperatures in which the FOUPs will remain in compliance with the requirements listed in §6. A temporary temperature range is the set of environmental temperatures to which the FOUPs can be exposed such that when the FOUPs return to the operating temperature range, the FOUPs will be in compliance with the requirements listed in §6. Limits on exposure times to elevated temperatures should be specified. Also, the purchaser needs to specify a range of temperatures for the wafers that might be inserted in the FOUPs.

5.3 *Fire Resistance* — The purchaser of 300 mm FOUPs may need to consider the flammability of the FOUPs.

5.4 *Info Pad Configurations* — The purchaser of 300 mm carriers needs to specify the desired info pad configuration (up or down).

## 6 Requirements

6.1 *Kinematic Couplings* — The physical alignment mechanism from the FOUP to the tool load-port (or a nest on a vehicle or in a stocker) consists of features (not specified in this standard) on the top entity that mate with three or six pins underneath as defined in SEMI E57. Most of the dimensions of the FOUP are determined with respect to the three orthogonal datum planes defined in that standard: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. All of the dimensions for the FOUP are bilaterally symmetric about both the bilateral and facial datum planes with the following exceptions:

- The features that mate with the kinematic coupling pins and the FOUP sensing pads are symmetrical only about the bilateral datum plane.
- The FOUP has a door only on the front and conveyor rails on the left and right sides that are required to extend all the way to the front.
- The orientation notches on the robotic handling flange are different for each of the four sides.

The three features that mate with the kinematic coupling pins must provide a lead-in capability that corrects a FOUP misalignment of up to *r*69 in any horizontal direction.

6.2 (This section, *"Internal Kinematic Couplings"* is no longer applicable, and is intentionally left blank so as to maintain paragraph numbering.)

6.3 *Interior Dimensions* — The interior of the FOUP must have the interior dimensions of the cassette specified in SEMI E1.9. Many of these dimensions are measured from a horizontal datum plane, so an internal horizontal datum plane is still specified to be *z*44 above the horizontal datum plane under the FOUP.

6.4 *Door*

6.4.1 (This section (6.4.1) is no longer applicable, and is intentionally left blank so as to maintain paragraph numbering.)

6.4.2 , The FOUP door is on the front side of the FOUP (corresponding to the front side of the cassette where wafers are accessed so the door is perpendicular to the wafers and parallel to the facial datum plane), and the door and its frame must be designed to mate with a port that conforms to SEMI E62. Specifically, the FOUP door and its frame must have surfaces that mate with the seal zones and the reserved spaces for vacuum application (which includes all of the circles bounded by *r*38 except for the holes for the registration pins at the center of each circle) defined in ¶¶5.3 and 5.6 of SEMI E62 (which specifies *r*38). These FOUP door and frame surfaces must be a distance of *y*52 from the facial datum plane and must have a flatness of *y*42. No surface on the FOUP door may project further from the facial datum plane than the door seal zone and the reserved spaces for vacuum application. The door of the FOUP must also be designed so that when the FOUP is pressed against the FIMS port, both latch keys on the port are inserted to their full length. Furthermore, when the latch keys are turned more than 45° toward the position that unlocks the FOUP door from the FOUP, the latch key holes on the door must be such that the door is not removable from the latch keys.

6.5 *Wafer Capture and Centering* — When the FOUP is closed, the wafers must be captured in the FOUP to prevent movement during transport. Wafer capture must include gently pushing the wafers to the rear of the cassette to center them.

6.6 *Internal Dimensions* —The interior of any FOUP must not intrude on the end effector exclusion zone, and the inside of the door must not intrude more that *y*51 toward the facial datum plane. The interior of the FOUP between *y*11 and the door opening must not protrude higher than *z*6 above the internal horizontal datum plane and lower than *z*15 above the top nominal wafer plane. Horizontally, it must not protrude closer to the bilateral datum plane than *x*51 between *y*11 and *y*49 or closer than *x*52 between *y*49 and *y*52 (as shown in Figure 10). Dimensions *x*51, *x*52, *y*49, and *y*52 are specified in Table 1, and *y*11, *z*6, and *z*15 are specified in SEMI E1.9.

6.7 *External Dimensions* — Figures 5 through 8 show the side view, rear view, top view, and bottom view for the FOUP. Table 1 defines all of the dimensions. In this and following figures, the heaviest lines are used for surfaces that have tolerances (not surfaces that have only maximum or only minimum dimensions). If a FOUP identification tag is used, it must be located at the bottom rear centered on the bilateral datum plane and must be contained within the maximum outer dimensions of the FOUP.

NOTE 1: Figures 1 through 4 have been removed from this document.

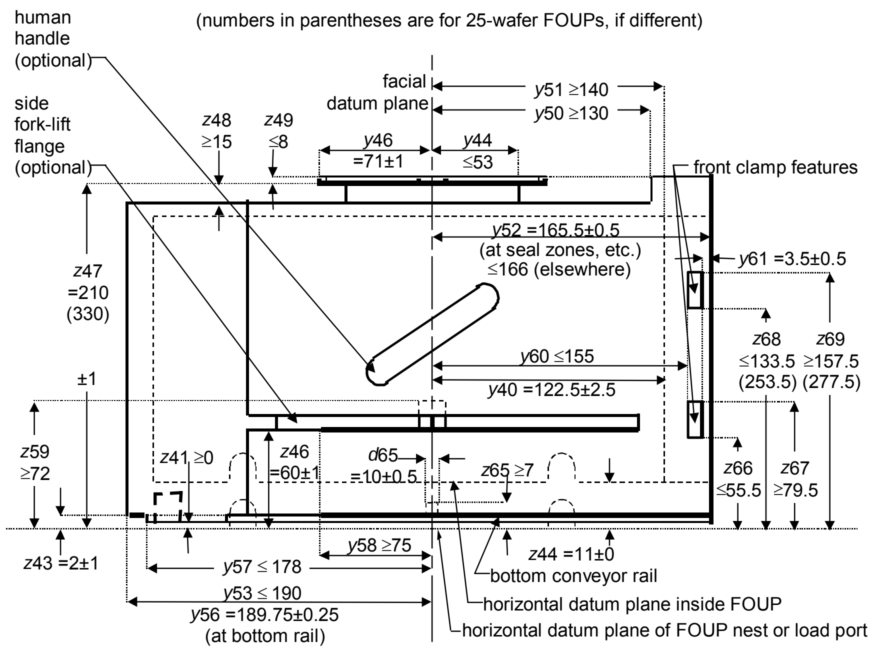


**Figure 5**
**Side View of FOUP**

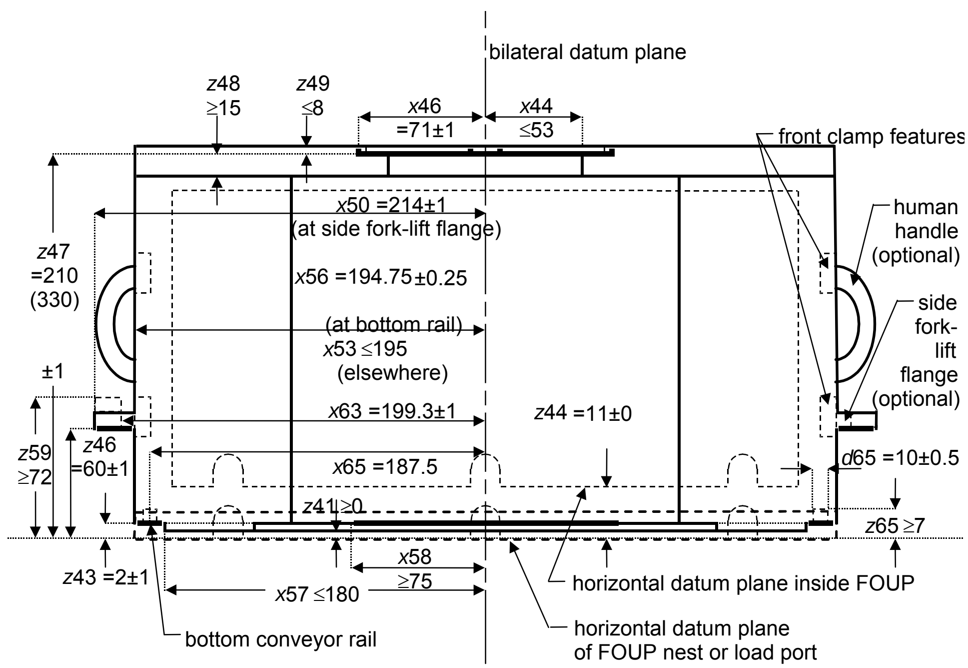


**Figure 6**
**Rear View of FOUP**

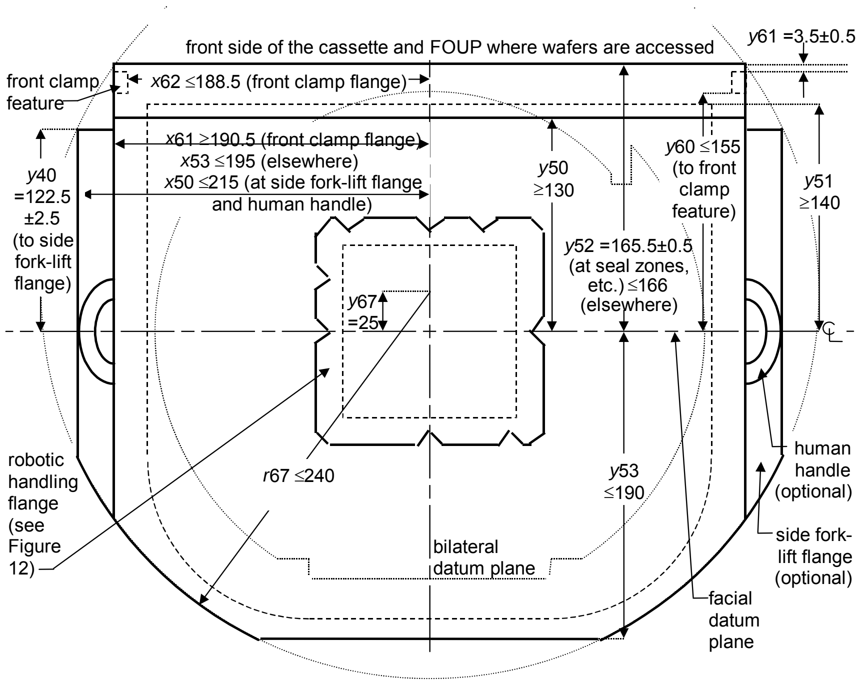


**Figure 7**
**Top View of FOUP**

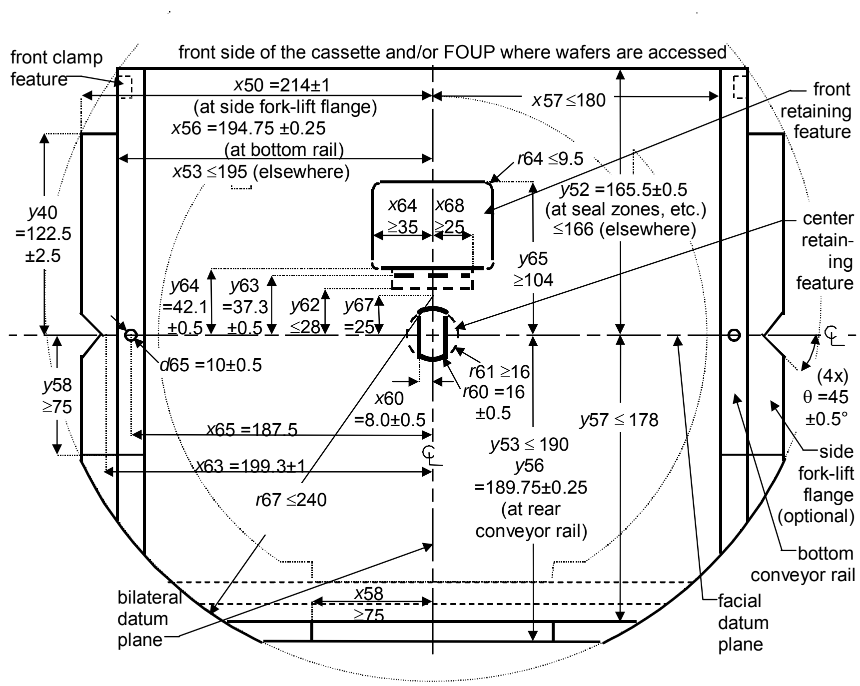


**Figure 8**
**Bottom View of FOUP**

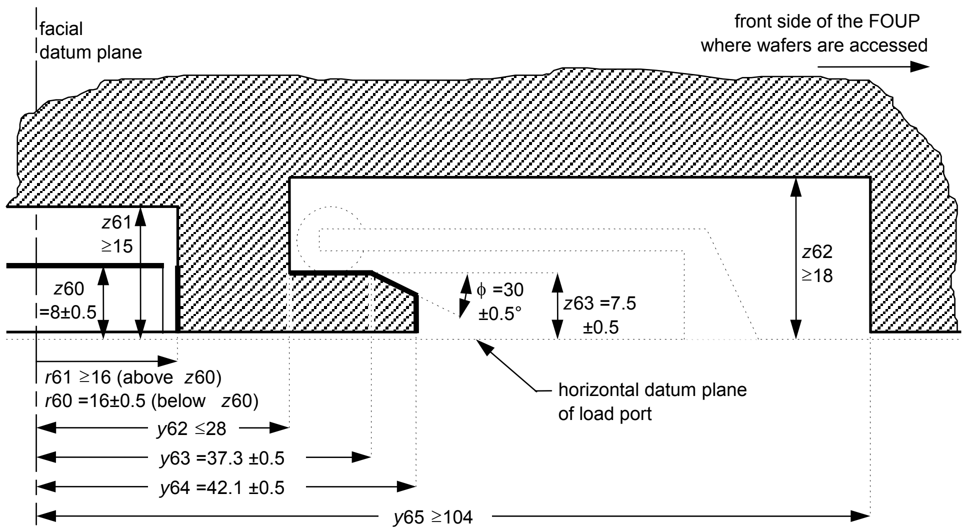


**Figure 9**
**Side View of Retaining Features on Bottom of FOUP**

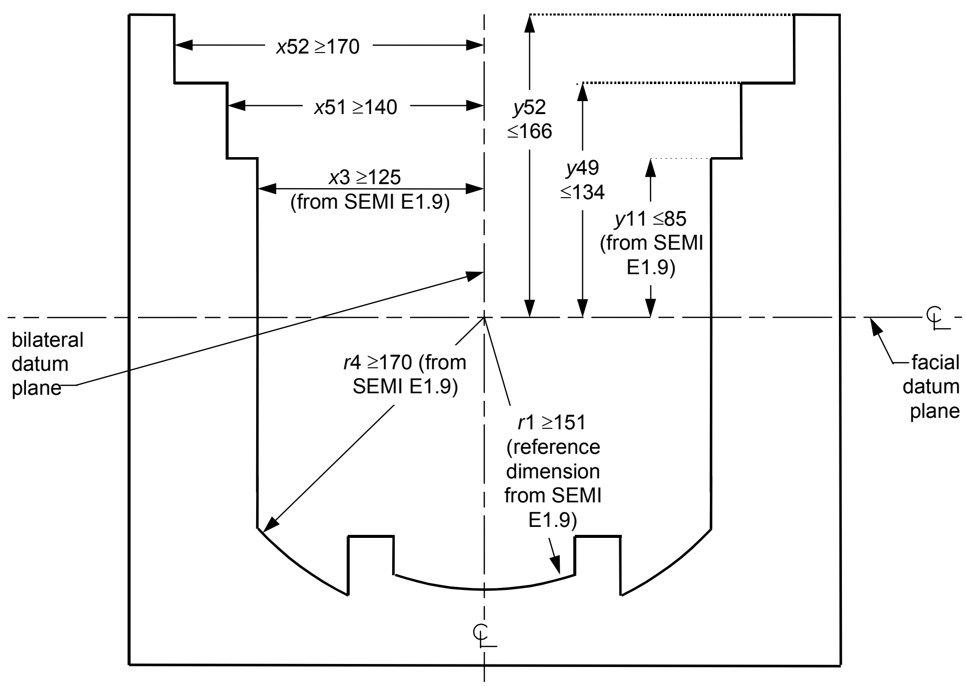


**Figure 10**
**Exclusion Volume Inside FOUP**

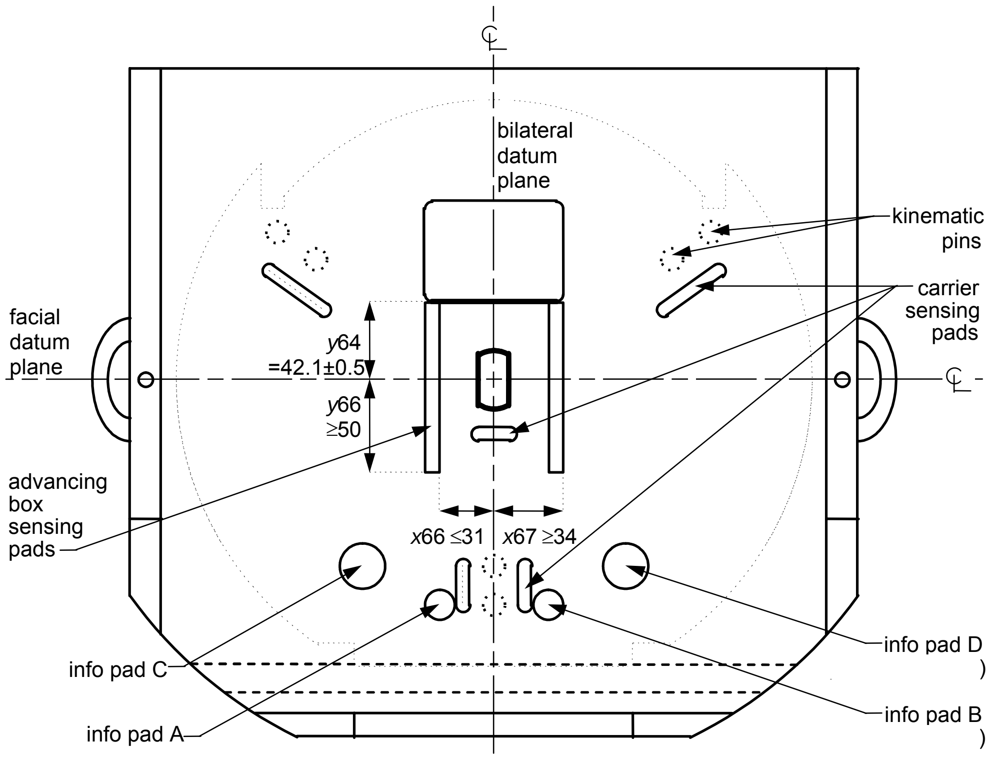


**Figure 11**
**Sensing Pads on Bottom of FOUP**

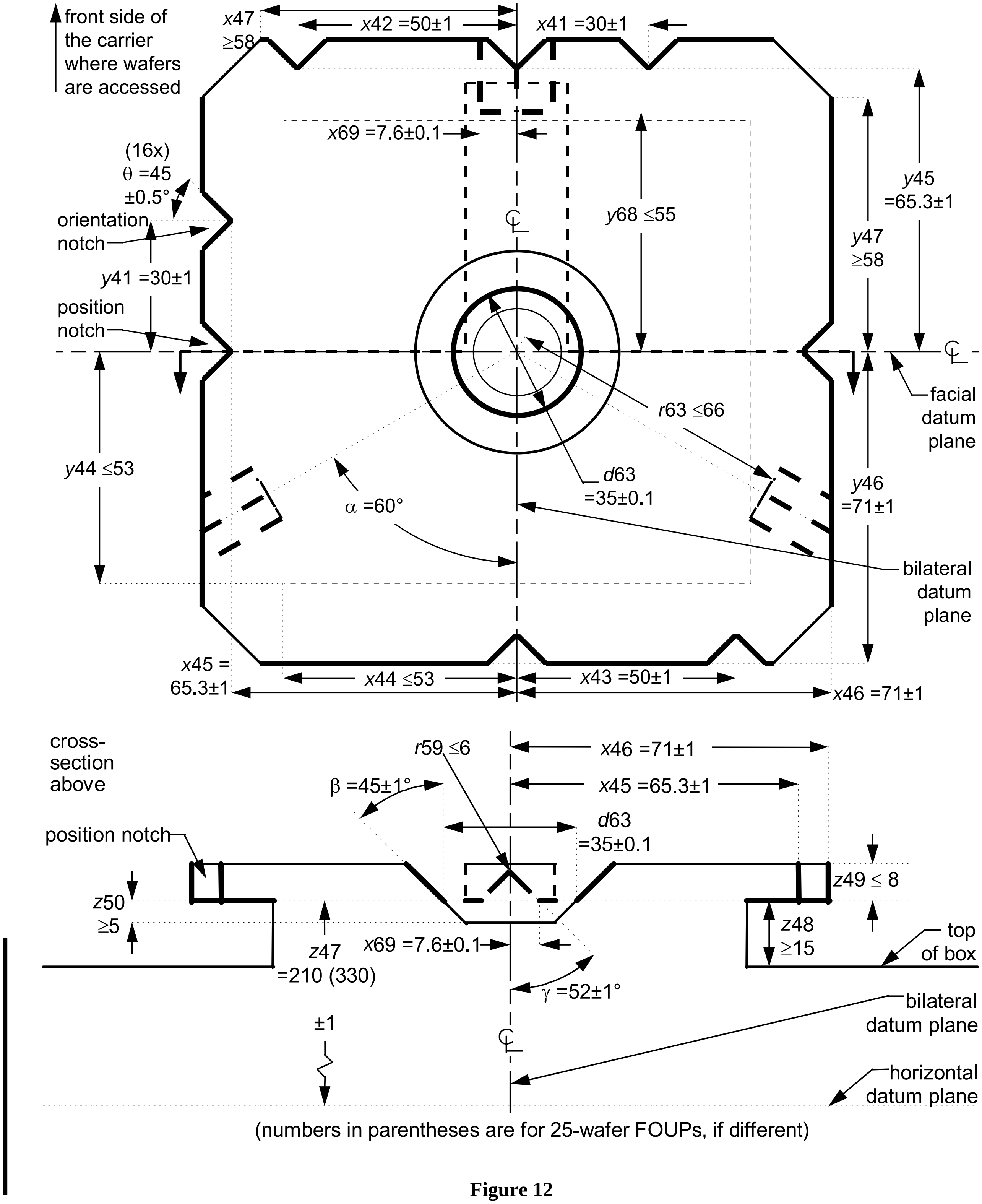


**Figure 12**
**Top Robotic Handling Flange**

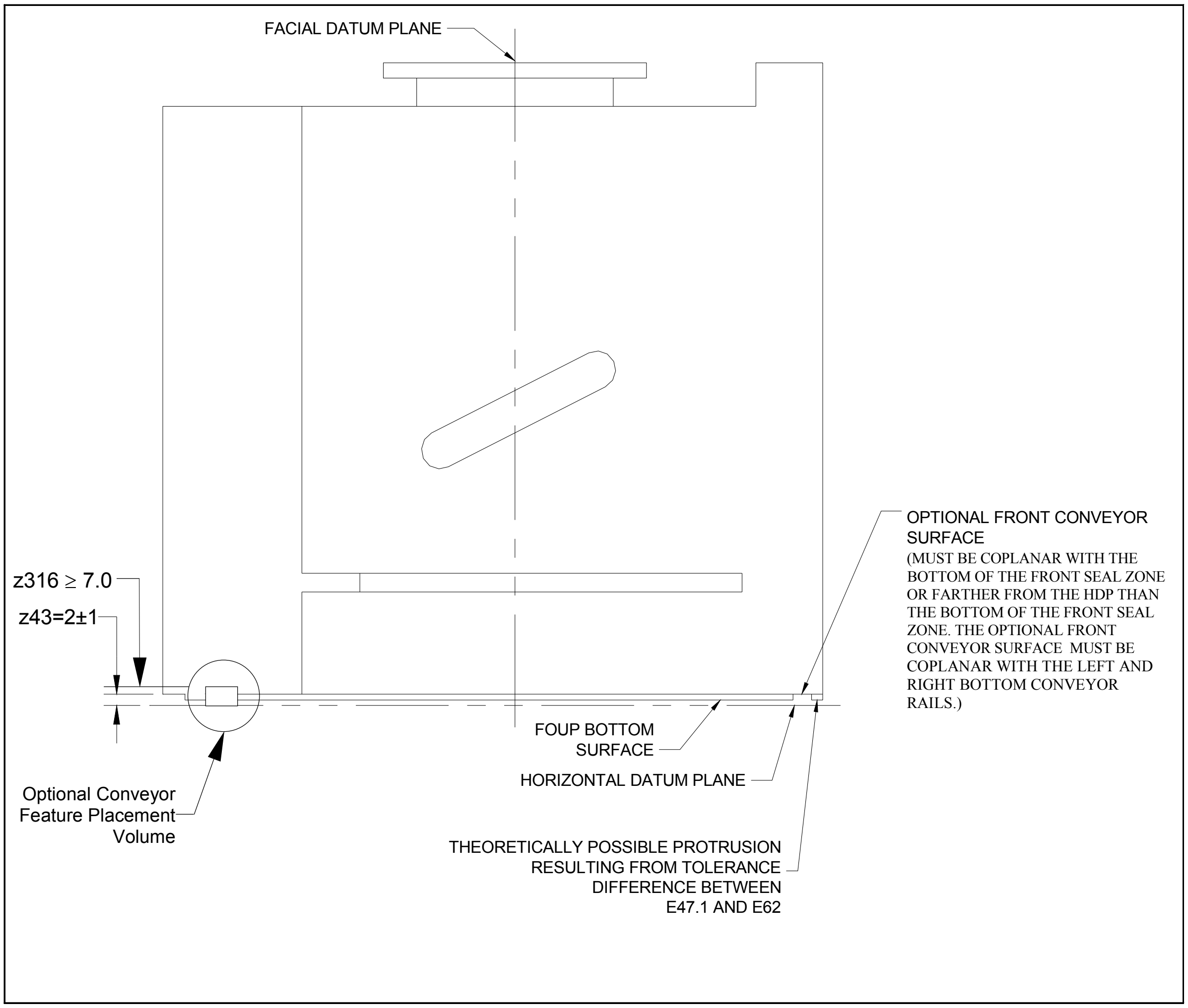


**Figure 13**
**Side View of FOUP Showing Optional Front Conveyor Surface Feature**

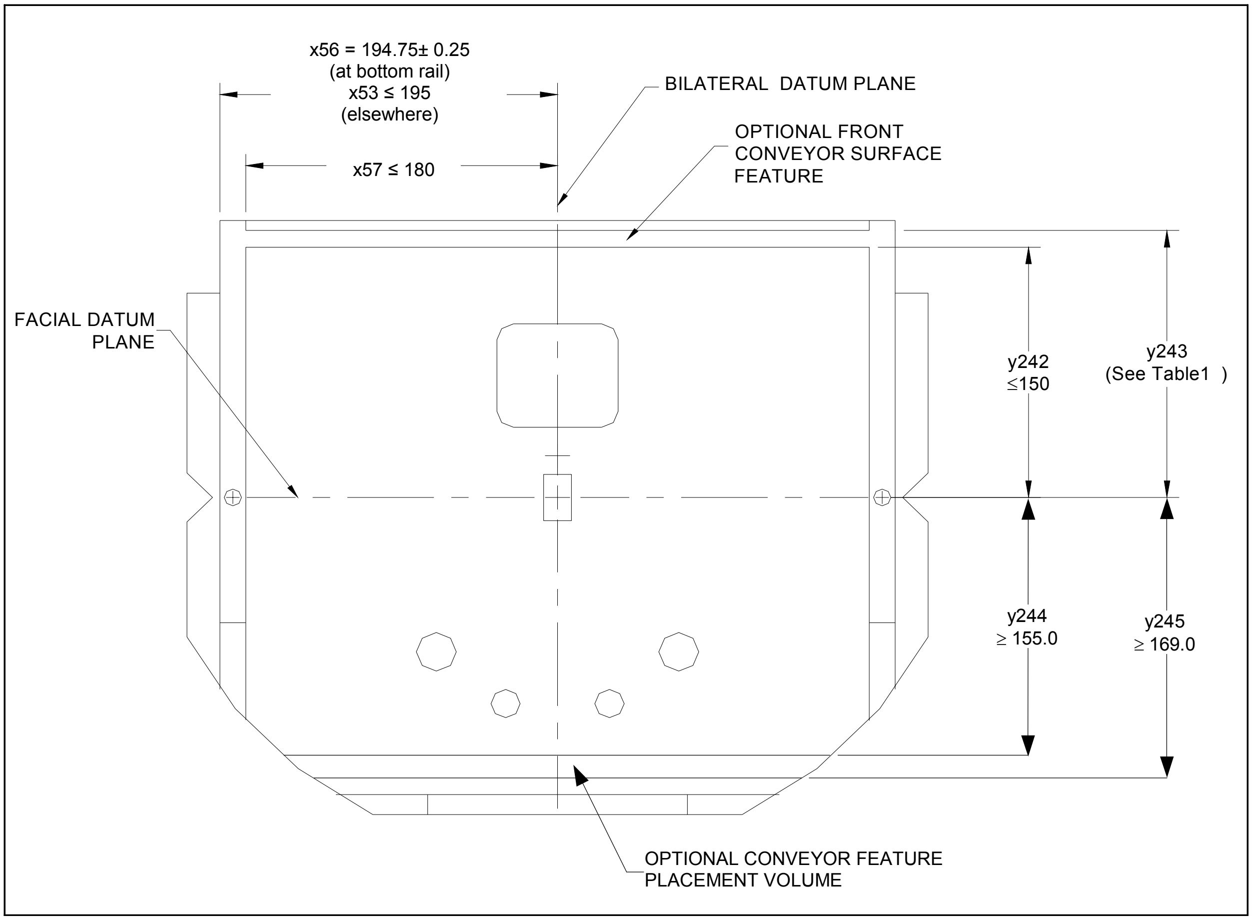


**Figure 14**
**Bottom View of FOUP Showing Optional Conveyor Features**

**Table 1 Dimensions for FOUP**

| *Symbol Used* | *Value Specified* | *Datum Measured From* | *Feature Measured To* |
|---|---|---|---|
| α‡ | 60° | bilateral datum plane | center line of the right and left kinematic grooves in the top robotic handling flange |
| β | 45 ± 1° | nominal wafer center line | surface of the center hole in the top robotic handling flange |
| γ‡ | 52 ± 1° | bilateral datum plane or vertical plane rotated α away from it about nominal wafer center line | angled surface of the kinematic grooves in the top robotic handling flange |
| θ‡ | 45 ± 0.5° | either vertical datum plane | sides of notches in the top robotic handling flange and in the side fork-lift flanges |
| ϕ | 30 ± 0.5° | horizontal line on bilateral datum plane | ramp of front retaining feature |
| *d*63 | 35 ± 0.1 mm (1.378 ± 0.004 in.) | diameter centered on the nominal wafer center line | sides the center hole in the top robotic handling flange at height *z*47 |
| *d*65 | 10 ± 0.5 mm (0.39 ± 0.02 in.) | diameter centered on the intersection of *x*65 and the facial datum plane | surface of cylindrical fork-lift pin holes in left and right bottom conveyor rails |
| *f*60 | 175 N (39.3 lbf.) minimum | not applicable | force in any direction which both retaining features are able to withstand |
| *r*59‡ | 6 mm (0.24 in.) maximum | not applicable | radius on peak of kinematic grooves in the top robotic handling flange |
| *r*60 | 16 ± 0.5 mm (0.63 ± 0.02 in.) | nominal wafer center line | ends of slot for center retaining feature |
| *r*61 | 16 mm (0.63 in.) minimum | nominal wafer center line | walls of chamber above slot in center retaining feature |
| *r*63‡ | 66 mm (2.60 in.) maximum | nominal wafer center line | near end of the right and left kinematic grooves in the top robotic handling flange |
| *r*64 | 9.5 mm (0.37 in.) maximum | not applicable | corners of front retaining feature |
| *r*65 | 1 mm (0.04 in.) maximum | not applicable | all concave features (radius) |
| *r*66 | 2 mm (0.08 in.) maximum | not applicable | all required convex features (radius) |
| *r*67 | 240 mm (9.45 in.) maximum | *y*67 in front of nominal wafer center line | any part of FOUP |
| *r*69 | 10 mm (0.4 in.) minimum (required)<br>15 mm (0.6 in.)<br>(recommended for ergonomic reasons) | not applicable | correctable FOUP misalignment in any horizontal direction |
| *x*41 | 30 ± 1 mm (1.18 ± 0.04 in.) | bilateral datum plane | front right orientation notch on robotic handling flange |
| *x*42 | 50 ± 1 mm (1.97 ± 0.04 in.) | bilateral datum plane | front left orientation notch on robotic handling flange |
| *x*43 | 50 ± 1 mm (1.97 ± 0.04 in.) | bilateral datum plane | rear orientation notch on robotic handling flange |
| *x*44 | 53 mm (2.09 in.) maximum | bilateral datum plane | encroachment of FOUP underneath robotic handling flange |
| *x*45 | 65.3 ± 1 mm (2.57 ± 0.04 in.) | bilateral datum plane | nearest point of side position and orientation notches on robotic handling flange |

| *Symbol Used* | *Value Specified* | *Datum Measured From* | *Feature Measured To* |
|---|---|---|---|
| *x*46 | 71 ± 1 mm (2.80 ± 0.04 in.) | bilateral datum plane | sides of robotic handling flange |
| *x*47 | 58 mm (2.28 in.) minimum | bilateral datum plane | end of robotic handling flange front and rear |
| *x*50‡ | 214 ± 1 mm (8.43 ± 0.04 in.) | bilateral datum plane | outer edge of side fork-lift flanges and furthest reach of human handles |
| *x*51 | 140 mm (5.51 in.) minimum | bilateral datum plane | interior of FOUP sides between *y*11 and *y*49 |
| *x*52 | 170 mm (6.69 in.) minimum | bilateral datum plane | interior of FOUP sides between *y*49 and *y*52 |
| *x*53 | 195 mm (7.68 in.) maximum | bilateral datum plane | FOUP sides (apart from human handles) |
| *x*56 | 194.75 ± 0.25 mm (7.667 ± 0.010 in.) | bilateral datum plane | outside edge of bottom conveyor rails |
| *x*57 | 180 mm (7.09 in.) maximum | bilateral datum plane | FOUP sides underneath bottom conveyor rails |
| *x*58‡ | 75 mm (2.95 in.) minimum | bilateral datum plane | end of rear conveyor rails |
| *x*60 | 8 ± 0.5 mm (0.31 ± 0.02 in.) | bilateral datum plane | sides of slot for center retaining feature |
| *x*61 | 190.5 mm (7.50 in.) minimum | bilateral datum plane | outer edge of front clamp flange |
| *x*62 | 188.5 mm (7.42 in.) maximum | bilateral datum plane | encroachment of FOUP behind front clamp flange |
| *x*63‡ | 199.3 ± 1 mm (7.85 ± 0.04 in.) | bilateral datum plane | nearest point of notches in side fork-lift flanges |
| *x*64 | 35 mm (1.38 in.) minimum | bilateral datum plane | sides of front retaining feature |
| *x*65 | 187.5 mm (7.38 in.) | bilateral datum plane | vertical axis of cylindrical fork-lift pin holes in left and right bottom conveyor rails |
| *x*66 | 31 mm (1.22 in.) maximum | bilateral datum plane | near side of advancing FOUP sensing pads |
| *x*67 | 34 mm (1.34 in.) minimum | bilateral datum plane | far side of advancing FOUP sensing pads |
| *x*68 | 25 mm (0.98 in.) minimum | bilateral datum plane | sides of volume above ramp on front retaining feature |
| *x*69‡ | 7.6 ± 0.1 mm (0.299 ± 0.004 in.) | bilateral datum plane or vertical plane rotated α away from it about nominal wafer center line | beginning of angled surface of the kinematic grooves in the top robotic handling flange |
| *y*40 | 122.5 ± 2.5 mm (4.82 ± 0.10 in.) | facial datum plane | front of side fork-lift flanges and furthest reach of human handles toward the front |
| *y*41 | 30 ± 1 mm (1.18 ± 0.04 in.) | facial datum plane | left orientation notch on robotic handling flange |
| *y*42 | ± 0.5 mm (± 0.02 in.) flatness over each area | not applicable | door and frame seal zones and the reserved spaces for vacuum application |
| *y*44 | 53 mm (2.09 in.) maximum | facial datum plane | encroachment of FOUP underneath robotic handling flange |
| *y*45 | 65.3 ± 1 mm (2.57 ± 0.04 in.) | facial datum plane | nearest point of front and rear position and orientation notches on robotic handling flange |

| *Symbol Used* | *Value Specified* | *Datum Measured From* | *Feature Measured To* |
|---|---|---|---|
| *y*46 | 71 ± 1 mm (2.80 ± 0.04 in.) | facial datum plane | front and rear edge of robotic handling flange |
| *y*47 | 58 mm (2.28 in.) minimum | facial datum plane | end of robotic handling flange sides |
| *y*49 | 134 mm (5.28 in.) maximum | facial datum plane | interior of FOUP sides between *x*51 and *x*52 |
| *y*50 | 130 mm (5.12 in.) minimum | facial datum plane | rear of upper door frame volume |
| *y*51 | 140 mm (5.51 in.) minimum | facial datum plane | rear of door |
| *y*52 | 165.5 ± 0.5 mm (6.52 ± 0.02 in.) at door and frame seal zones and at reserved spaces for vacuum application and 166 mm (6.54 in.) maximum elsewhere on door or FOUP shell | facial datum plane | FOUP front |
| *y*53 | 190 mm (7.48 in.) maximum | facial datum plane | FOUP rear |
| *y*56‡ | 189.75± 0.25 mm (7.470 ± 0.010 in.) | facial datum plane | outside edge of front and rear bottom conveyor rails |
| *y*57‡ | 178 mm (7.01 in.) maximum | facial datum plane | encroachment of FOUP front and rear underneath bottom conveyor rails |
| *y*58 | 75 mm (2.95 in.) minimum | facial datum plane | end of left and right conveyor rails |
| *y*60 | 155 mm (6.10 in.) maximum | facial datum plane | encroachment of FOUP behind front clamp flange |
| *y*61 | 3.5 ± 0.5 mm (0.14 ± 0.02 in.) | front of front clamp flange at FOUP front | rear of front clamp flange |
| *y*62 | 28 mm (1.10 in.) maximum | facial datum plane | rear of front retaining feature |
| *y*63 | 37.3 ± 0.5 mm (1.47 ± 0.02 in.) | facial datum plane | rear of ramp on front retaining feature |
| *y*64 | 42.1 ± 0.5 mm (1.66 ± 0.02 in.) | facial datum plane | front of ramp on front retaining feature and front side of advancing FOUP sensing pads |
| *y*65 | 104 mm (4.09 in.) minimum | facial datum plane | front of front retaining feature |
| *y*66 | 50 mm (1.97 in.) minimum | facial datum plane | rear side of advancing FOUP sensing pads |
| *y*67 | 25 mm (0.98 in.) | facial datum plane | origin of *r*67 on bilateral datum plane |
| *y*68‡ | 55 mm (2.17 in.) maximum | facial datum plane | near end of the front kinematic groove in the top robotic handling flange |
| *y*242‡ | 150 mm (5.75 in.) maximum | facial datum plane | front conveyor surface edge closest to facial datum plane |
| *y*243‡ | If the front conveyor surface is farther from HDP than the front conveyor rail (defined by bottom of front seal zone):<br>161.0 mm (1.0 mm<br>(6.34 (0.04 in.) | facial datum plane | front conveyor surface edge furthest from facial datum plane |
| | If the front conveyor surface is coplanar with the front conveyor rail (defined by bottom of front seal zone):<br>165.5 mm (0.5 mm<br>(6.52 (0.02 in.) | | |
| *y*244‡ | 155.0 mm maximum | facial datum plane | rear conveyor placement volume front boundary |
| *y*245‡ | 169.0 mm minimum | facial datum plane | rear conveyor placement volume rear boundary |

| Symbol Used | Value Specified | Datum Measured From | Feature Measured To |
|---|---|---|---|
| z316‡ | 7.0 mm minimum | horizontal datum plane | rear conveyor placement volume upper boundary |
| z2 | 2 mm (0.08 in.) maximum | horizontal datum plane | bottom of carrier sensing pads and info pads (when down) |
| z41 | 0 mm (0 in.) minimum | external horizontal datum plane | bottom of FOUP |
| z43 | 2 ± 1 mm (0.08 ± 0.04 in.) | external horizontal datum plane | bottom conveyor rails |
| z44 | 11 ± 0 mm<br>(0.43 ± 0 in.) | external horizontal datum plane | internal horizontal datum plane |
| z46‡ | 60 ± 1 mm<br>(2.36 ± 0.04 in.) | external horizontal datum plane | bottom of side fork-lift flanges |
| z47 | 210 ± 1 mm<br>(8.27 ± 0.04 in.)<br>for 13-wafer FOUP and<br>330 ± 1 mm<br>(12.99 ± 0.04 in.)<br>for 25-wafer FOUP | external horizontal datum plane | bottom of robotic handling flange |
| z48 | 15 mm (0.59 in.) minimum | bottom of robotic handling flange | encroachment of FOUP top underneath robotic handling flange |
| z49 | 8 mm (0.31 in.) maximum | bottom of robotic handling flange | top of robotic handling flange and upper door frame volume |
| z50 | 5 mm (0.20 in.) minimum | bottom of robotic handling flange | encroachment of FOUP top underneath the center hole in the top robotic handling flange |
| z59 | 72 mm (0.31 in.) minimum | external horizontal datum plane | top of notches in side fork-lift flanges |
| z60 | 8.0 ± 0.5 mm<br>(0.31 ± 0.02 in.) | external horizontal datum plane | top of slot in center retaining feature |
| z61 | 15 mm (0.59 in.) minimum | external horizontal datum plane | top of chamber above slot in center retaining feature |
| z62 | 18 mm (0.71 in.) minimum | external horizontal datum plane | top of front retaining feature |
| z63 | 7.5 ± 0.5 mm<br>(0.30 ± 0.02 in.) | external horizontal datum plane | top of ramp on front retaining feature |
| z65 | 7 mm (0.28 in.) minimum | horizontal datum plane | upper boundary of cylindrical fork-lift pin holes in left and right bottom conveyor rails |
| z66 | 55.5 mm (2.19 in.) maximum | external horizontal datum plane | encroachment of FOUP behind bottom front clamp flange |
| z67 | 79.5 mm (3.13 in.) minimum | external horizontal datum plane | encroachment of FOUP behind bottom front clamp flange |
| z68 | 133.5 mm (5.26 in.) maximum<br>for 13-wafer FOUP and<br>253.5 mm (9.98 in.) maximum<br>for 25-wafer FOUP | external horizontal datum plane | encroachment of FOUP behind top front clamp flange |
| z69 | 157.5 mm (6.20 in.) minimum<br>for 13-wafer FOUP and<br>277.5 mm (10.93 in.) minimum<br>for 25-wafer FOUP | external horizontal datum plane | encroachment of FOUP behind top front clamp flange |

‡ These dimensions define optional features.