# APPENDIX 2
# ADDITIONAL INFORMATION

**NOTICE**: The material in this appendix is an official part of SEMI E100 and was approved by full letter ballot procedures on September 3, 1999 by the North American Regional Standards Committee.

A2-1 Features on the RSP which enable stacking may be standardized in the future pending learning from first design approaches and standardization of reticle ID location.

# SEMI E101-1104
# GUIDE FOR EFEM FUNCTIONAL STRUCTURE MODEL

This guide was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the North American Physical Interfaces and Carriers Committee. Current edition approved by the North American Regional Standards Committee on August 16, 2004. Initially available at www.semi.org September 2004, to be published November. Originally published February 2000; previously published October 2000.

## 1 Purpose

1.1 Productivity improvement is the task with the highest priority in semiconductor factories of the 300 mm generation, and computer-integrated manufacturing or factory automation (CIM/FA) technologies become more and more important to accomplish it. The standardization of these technologies is also necessary to provide the CIM/FA infrastructure in a short period of time at a low cost. Since the standards will have to cover a wide range of production equipment, communication hardware, and software tools, it is very important that the standards have a high degree of compatibility. In order to improve the compatibility, this guide provides a functional structure model of an Equipment Front End Module (EFEM) that handles carriers and substrates at the interface between the factory material handling system and the process equipment.

1.2 The major purposes of this guide are as follows:

1) provide a common understanding of functions of EFEM (Equipment Front End Module) and associated interfaces between functional elements (components with particular function roles),

2) provide a common understanding of the hierarchical structure of functions and their interfaces in an EFEM,

3) provide a common understanding of possible units used for maintenance, adjustment, and control, and

4) provide a map between EFEM functional elements and existing standards.

## 2 Scope

2.1 *Model Structure and Functions*

2.1.1 This document recognizes EFEM as a component of semiconductor manufacturing equipment. It creates an EFEM functional structure model to clearly describe EFEM, its functional elements, and the functions of each functional element. The functional structure model includes the following:

1) definition of functional elements that constitute EFEM,

2) definition of functions of functional elements, and

3) hierarchical description of functional elements.

2.1.2 For clarity, Fixed Buffer Type EFEM and Internal Buffer Type EFEM (see Terminology) are represented as independent functional structure models in this document.

2.2 *Preconditions for Modeling*

2.2.1 The models are created under the following conditions:

1) Modeling should be restricted to SEMI E15.1, Option 1, Options 2 and 3, and Option 3 types. (See SEMI E15.1, Figure 2 (Load Port Options)).

2) The model supports handling of open cassette (OC), and Front Opening Unified Pod (FOUP) (see Terminology).

3) The model is created for the maximum structure including options.

4) Functional elements that have interfaces with EFEM are also included in the model.

NOTE 1: Functional elements that don't belong to EFEM, but are important in defining interfaces among the functional elements, are represented in this model to clarify their functional positions and attributes in the entire equipment.

**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 E23 — Specification for Cassette Transfer Parallel I/O Interface

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

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

SEMI E64 — Specification for 300 mm Cart to SEMI E15.1 Docking Interface Port

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

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

## 4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 AGV — automatic guided vehicle (cart)

4.1.2 *OHT* — overhead transport system with hoist for lifting carriers between load port level and transport level.

4.1.3 *PGV* — person guided vehicle (cart).

4.1.4 *PI/O* — parallel input/output interface, for example, as specified in SEMI E23.

4.1.5 *RGV* — rail guided vehicle (moving on the floor).

4.2 *Definitions*

4.2.1 *BOLTS plane* — a plane parallel to the facial datum plane near the front of the tool where the box opener/loader is attached (as defined in SEMI E63).

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

4.2.3 *box opener/loader* — the equipment component that opens wafer carriers (if needed) and presents the carriers to the equipment's Substrate Handler for unloading and loading wafers.

4.2.4 *carrier* — any cassette, box, or pod that are used to transport substrates (as defined in SEMI E15).

4.2.5 *cart* — a floor-based carrier transfer vehicle.

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

4.2.7 *docking* — the act of locating a floor-based carrier transport vehicle for carrier transfer to/from equipment.

4.2.8 *equipment front end module (EFEM)* — it consists of the carrier handler that receives carriers from the factory material handling system on one or more load ports (as specified in SEMI E15.1), opens the carriers (if needed), and may include a Substrate Handler for unloading and loading wafers from the carrier to the process part of equipment.

4.2.9 *fixed buffer* — EFEM configuration with carrier places only on load port units arranged in a load port group.

4.2.10 *front opening unified pod (FOUP)* — front opening type box/pod with non-removable cassettes (as defined in SEMI E47.1).

4.2.11 *internal buffer* — EFEM configuration with carrier places different from load port units.

4.2.12 *kinematic coupling* — the physical alignment mechanism on the bottom of the wafer carrier that consists of features that mate with three vertical pins on the load port (as defined in SEMI E57).

4.2.13 *load port* — the interface location on a tool where carriers are placed to allow the tool to process wafers (as defined in SEMI E15).

4.2.14 *open cassette (OC)* — a cassette (as defined in SEMI E1.9) without a protective barrier around it.

4.2.15 *transfer* — to either load or unload (as defined in SEMI E15).

## 5 Modeling Methodology (General Rules)

5.1 *Notation*

5.1.1 A functional element to be defined is represented by a rectangle.

5.1.2 The name of a functional element is written in the rectangle representing the element.

5.1.3 Numbers preceding the functional element name indicate the number of elements.

[0, 1] indicates the element may exist or may not exist.

[1+] indicates the element may exist one or more times.

5.2 *Rules of Notation Usage*

5.2.1 A functional element that is written on the border between adjacent layers indicates the element may belong to either of two functional elements in the adjacent layers.

5.2.2 Functional elements whose position in the Functional Structure Model diagram are similar in the two models of Fixed Buffer Type EFEM and Internal Buffer Type EFEM have the same name.

5.2.3 A functional element whose location is still undecided between two adjacent layers is located in between them.

## 6 Definition of Functional Elements

6.1 *Overall Structure*

6.1.1 Figures 1, 2 and Figures 3, 4 show conceptual structures of two types of Fixed Buffer Type EFEM model and two types of Internal Buffer Type EFEM model in overall structure of equipment. Two types of EFEM exist, when Substrate Handler is installed outside the Process Part, and when the Substrate Handler is included inside the Process Part.

6.1.2 *EFEM [1]* — This is a major module whose functions are to transfer carriers to and from the factory material handling system, to provide all carrier handling and storage functions for production equipment, and to load and unload substrates from the carrier for processing. It consists of a Carrier Handler and may contain a Substrate Handler.

6.1.3 *Carrier Handler [1]* — A Carrier Handler receives and passes the carriers from and/or to the external system (such as the factory material handling system). A Carrier Handler of the Internal Buffer Type has the functions of handling and storing the carriers. A carrier handler for FOUPs has the opener(s) for opening and closing FOUPs.

6.1.4 *Substrate Handler [0,1]* — A Substrate Handler transfers substrates between the carriers and the process part of the equipment.

6.1.5 *Load Port Group [1+]* — The load port group is where carriers are received and passed from or to the external system (such as the factory material handling system). Each equipment has at least one load port group. A load port group consists of one or more load ports.

1.1.5 *Internal Buffer [1+]* — This is a buffer that stores carriers inside equipment. It moves carriers from Load Port Group to Buffer and moves carriers from Buffer to Internal Substrate Port. It consists of a Carrier Transfer Robot that transfers the carriers to or from a Carrier Storage and a Carrier Storage where carriers are stored.

6.1.6 *Internal Substrate Port [0,1+]* — This is where substrates are loaded and unloaded from a carrier, and it contains any functionality required to present the carrier for substrate access.

6.2 *Definition of Functional Elements for EFEM Models*

6.2.1 *Model of Fixed Buffer Type EFEM (see Figure 5)*

6.2.1.1 *Load Port [1+]* — A load port is where an individual carrier is held for pickup and delivery with the factory material handling system. It consists of a Load Port Unit and may contain PI/O for OHT/AGV/RGV, Cart-to-Tool Docking Port Interface, and a Load Port Door.

6.2.1.2 *Load Port Unit [1]* — This physically receives carriers from/to external systems. It consists of a Carrier Opener/Loader, and it may contain a Carrier Operation Panel, a Carrier ID Reader/Writer, and a Carrier Slot Mapper.

6.2.1.3 *PI/O for AGV/RGV/OHT [0,1]* — This is a means of low-level communications that synchronizes the hand-off between Automated Material Handling equipment (such as AGV, RGV, OHT) and production equipment. One Parallel I/O may exist for each stop position of the AGV, RGV, or OHT. It may be a part of a Load Port or a Load Port Group depending on the number of ports that can be accessed from a single stop position.

6.2.1.4 *Cart-to-Tool Docking Port Interface [0,1]* — This is the mechanical interface allocated for installing the module to be used as a docking means for a person-guided vehicle (PGV) at the Load Port Group. One Cart-to-Tool Docking Port Interface may exists per Load Port Group or per Load Port.

6.2.1.5 *Load Port Door [0,1]* — This is the door that may be used to separate the space on a load port from the external environment, or to prevent the operator from interfering with the load port mechanism or OHT. This may be a part of a Load Port or a Load Port Group depending on the number of ports that can be accessed through a single Port Door.

6.2.1.6 *Carrier Operation Panel [0,1]* — This is an operation panel that may be used when manually loading or unloading a carrier to or from a Load Port. One operation panel may exist for each of SEMI E15.1's Load Port Option 1 and Option 3 types. No operation panel may exist for a Load Port of SEMI E15.1, Option 2 type.

6.2.1.7 *Manual Switches [0,1]* — These are the switches that may be used by an operator when manually loading or unloading a carrier. They are located on the Carrier Operation Panel.

6.2.1.8 *Carrier Indicators [0,1]* — These consist of a Carrier Presence Indicator (that indicates the presence of a carrier) and a Carrier Placement Indicator (that indicates whether the carrier is correctly seated). One set of Carrier Indicators may exist for each Load Port Unit. They are located on the Carrier Operation Panel.

6.2.1.9 *Carrier Opener/Loader [1]* — This is the unit that prepares a carrier for access for loading and unloading substrates and includes all mechanisms required for docking and undocking, purging, opening and closing FOUPs. In the case of an OC, it consists only of the Load Plate.

6.2.1.10 *Dock Plate [0,1]* — This is a mechanism that advances a FOUP up to the door opening/closing mechanism. It contains a Load Plate that a carrier is placed on, and it may contain the Dock/Undock mechanism that advances the carrier into the equipment, and/or a Carrier Purge Interface.

6.2.1.11 *Load Plate [1]* — This is the base plate on which carriers are placed. It consists of a Kinematic Coupling and may contain Carrier Sensors and/or Info Pad Sensors.

6.2.1.12 *Carrier Sensors [0,1]* — These are sensors to detect whether a carrier is present and/or a carrier is correctly placed.

6.2.1.13 *Info Pad Sensors [0,1]* — These are sensors to detect Info Pads as defined in SEMI E1.9.

6.2.1.14 *Carrier Purge Interface [0,1]* — This is a mechanical interface for injecting and withdrawing gasses.

6.2.1.15 *Dock/Undock Mechanism [0,1]* — This is the mechanism that advances a carrier to the FOUP opener and locks the carrier, or releases it from its locked state. In the OC (as defined in SEMI E1.9) case, this mechanism only moves carriers.

6.2.1.16 *FOUP Opener [0,1]* — This is the mechanism that opens and closes the FOUP door.

6.2.1.17 *Carrier Opener/Loader Maintenance Panel [0,1]* — This is a user interface for maintenance of the Carrier Opener/Loader.

6.2.1.18 *Carrier Slot Mapper [0,1]* — This is the mechanism that detects the presence or the absence of substrates and their positions in a carrier. It may be installed on the FOUP Opener, the Carrier Opener/Loader, the Load Port Unit, or the Substrate Handler.

6.2.1.19 *Carrier ID Reader/Writer [0,1]* — This is the unit that reads and/or writes to an ID tag attached to a carrier. At most, one Carrier ID Reader/Writer exists for each Load Port Unit.

6.2.1.20 *Status Indicator [0,1]* — This is a set of indicators which shows operating status of the Load Port Unit.

6.2.1.21 *Substrate ID Reader [0,1]* — This is the unit which reads the Identification Label on the Substrate.

6.2.1.22 *Aligner [0,1]* — This is the unit which aligns the angular orientation of substrates and may center the substrate.

6.2.1.23 *Substrate Transfer Robot [0,1+]* — This is the unit which transfers substrates between Carrier Handler, automation components (Aligner, Substrate ID Reader, etc.) and Process Part.

6.2.2 *Model of Internal Buffer Type EFEM (see Figure 6)*

6.2.2.1 This section defines functional elements that exist only in an Internal Buffer Type EFEM.

6.2.2.2 *Internal Buffer [1+]* — This is where an individual carrier is stored in an EFEM. It consists of a Carrier Transfer Robot that transfers carriers and a Carrier Storage where carriers are stored.

6.2.2.3 *Carrier Transfer Robot [1]* — This is a robot that handles carriers in Carrier Storage.

6.2.2.4 *Carrier Storage [1+]* — This is where an individual carrier is stored.

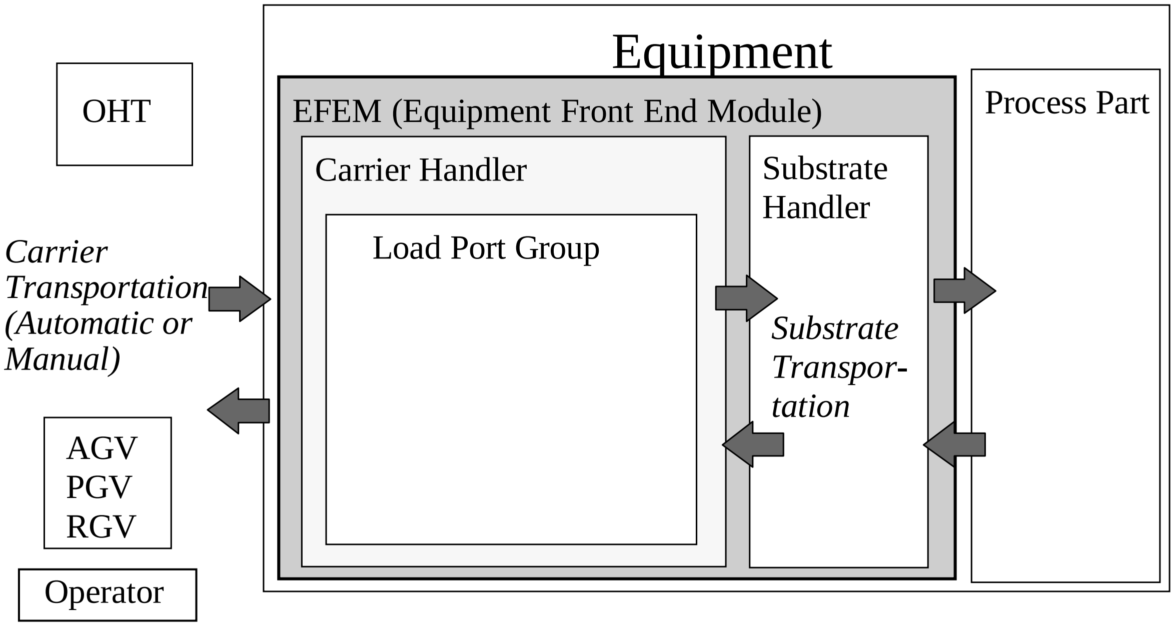


**Figure 1**
**Conceptual Structure of Fixed Buffer Type EFEM in Equipment W hen Substrate Handler Is Installed Outside Process Part**

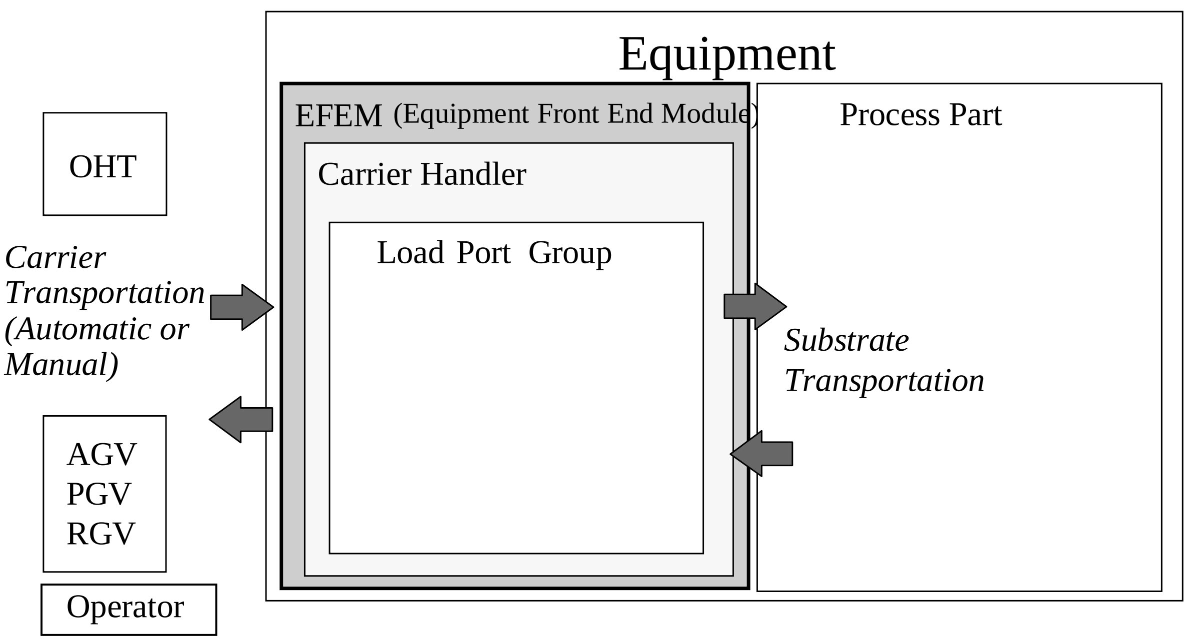


**Figure 2**
**Conceptual Structure Location of Fixed Buffer Type EFEM in Equipment When Substrate Handler Is Included Inside Process Part**

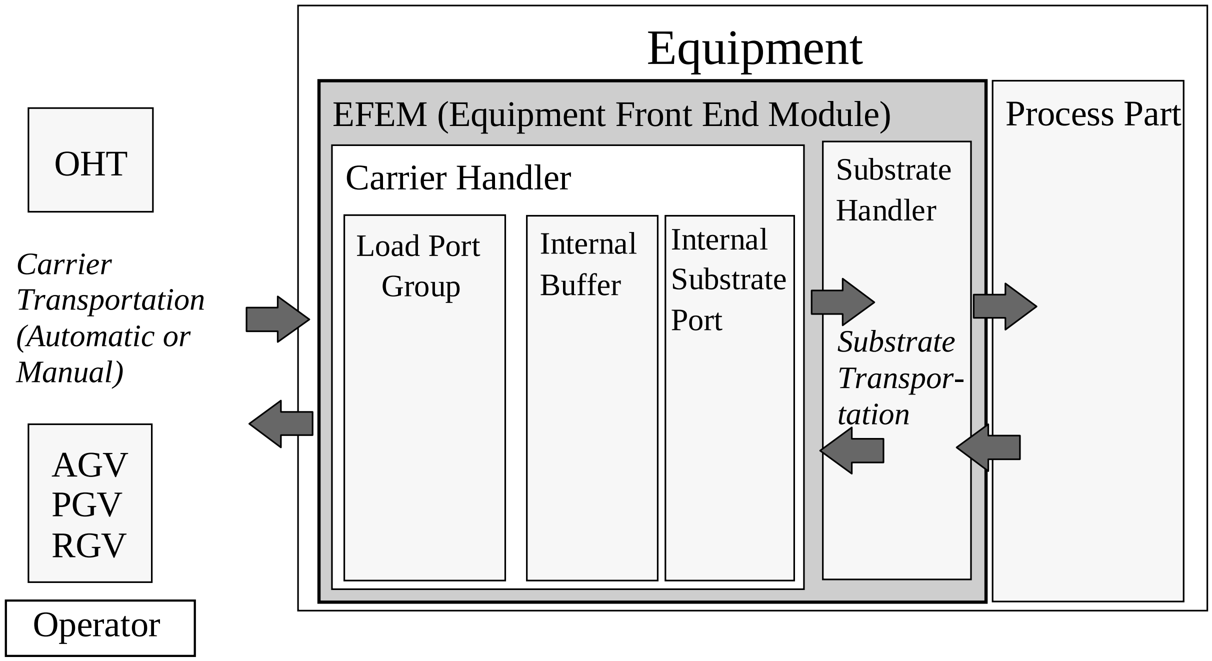


**Figure 3**
**Conceptual Structure of Internal Buffer Type EFEM in Equipment When Substrate Handler Is Installed Outside Process Part**

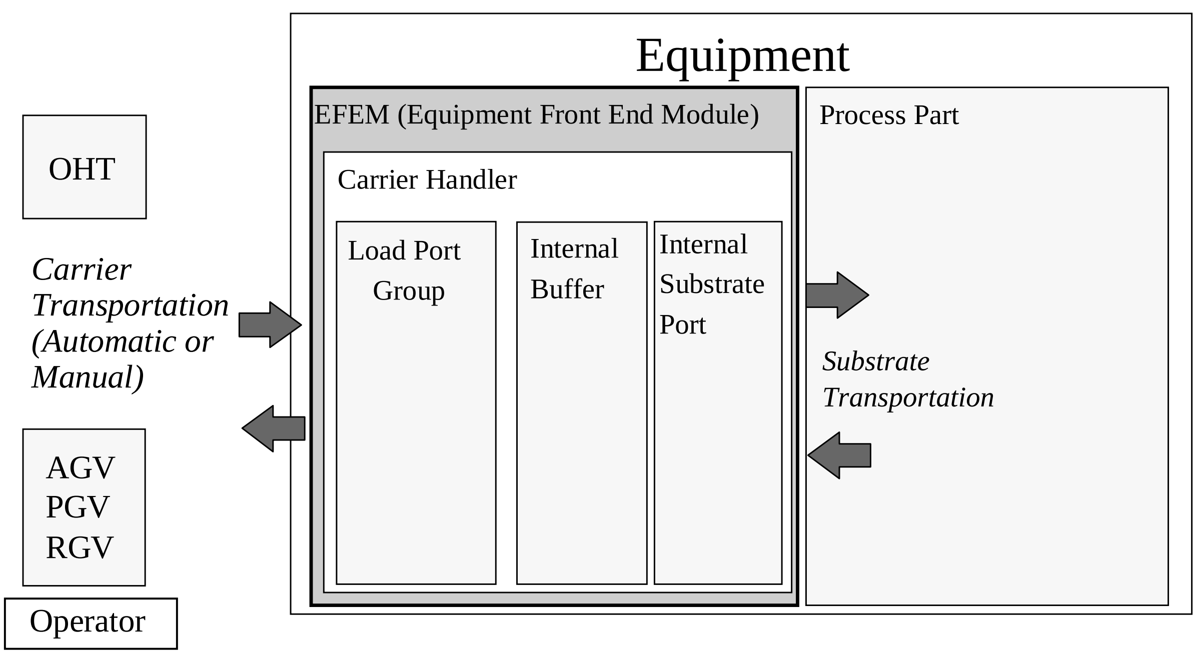


**Figure 4**
**Conceptual Structure of Internal Buffer Type EFEM in Equipment When Substrate Handler Is Included Inside Process Part**

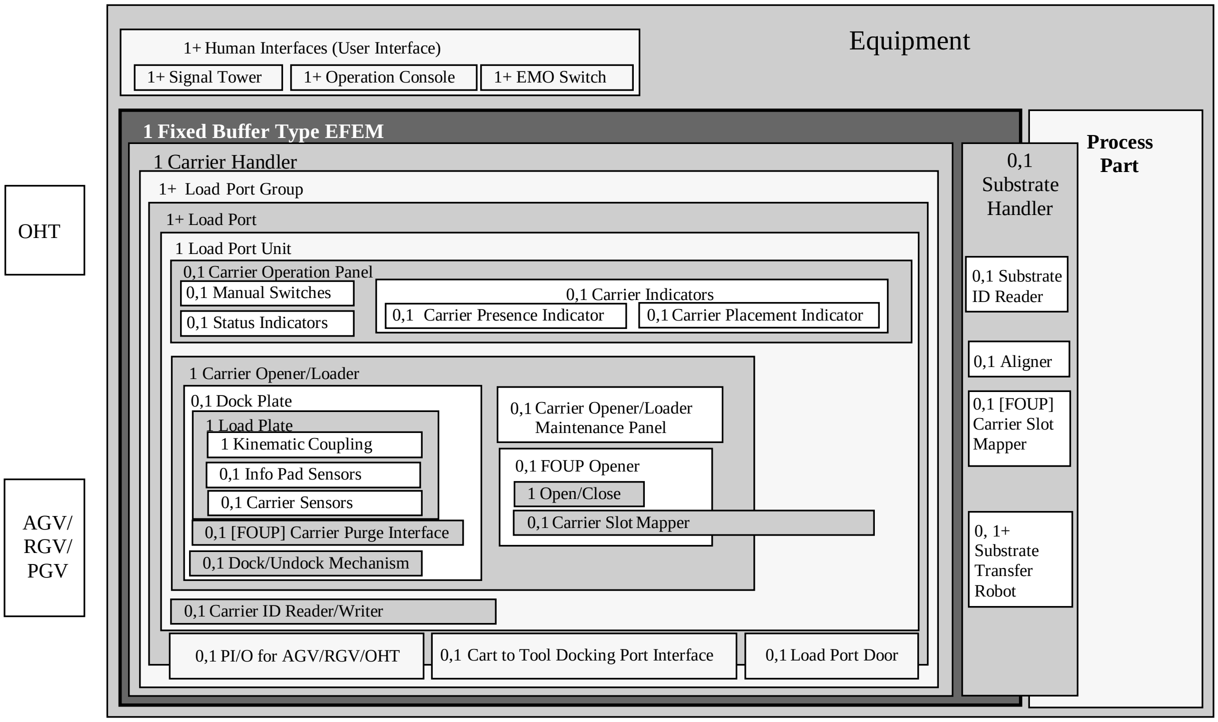


**Figure 5**
**Fixed Buffer Type EFEM Functional Structure Model**

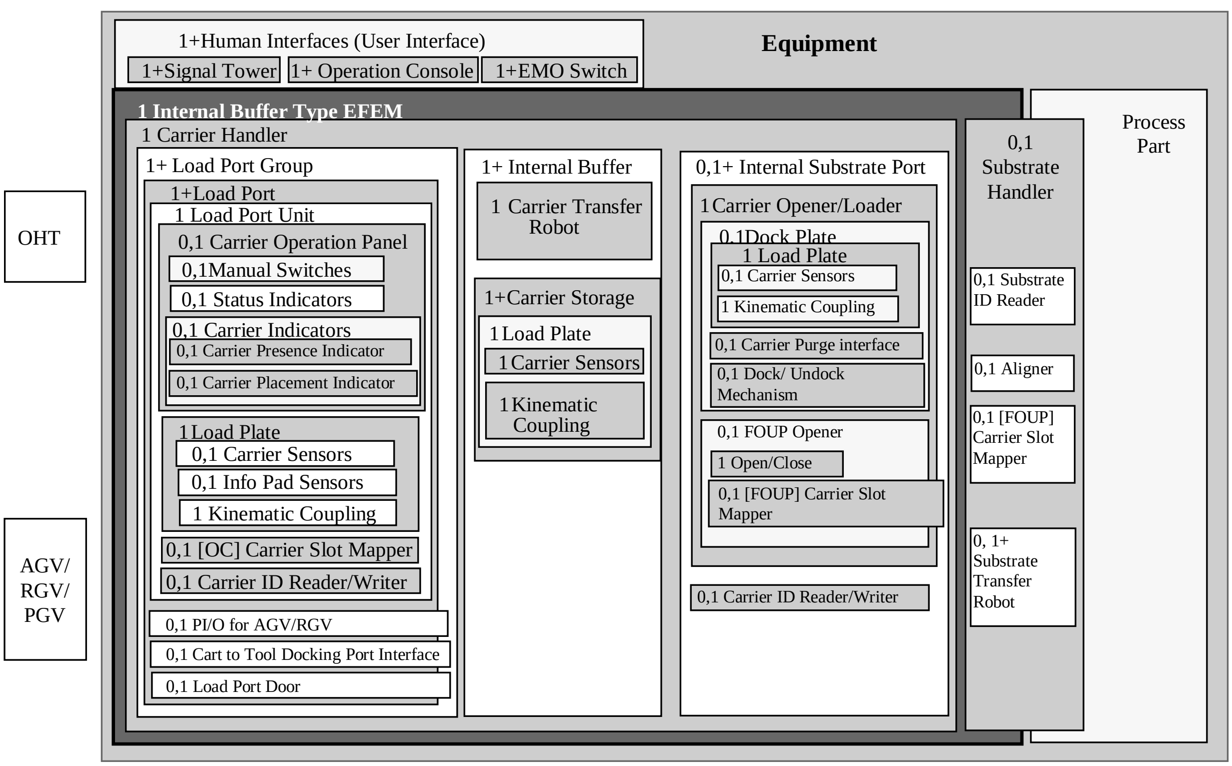


**Figure 6**
**Internal Buffer Type EFEM Functional Structure Model**

# APPENDIX 1

**NOTICE**: The material in this appendix is an official part of SEMI E101 and was approved by full letter ballot procedures on January 14, 2000 by the Japanese Regional Standards Committee.

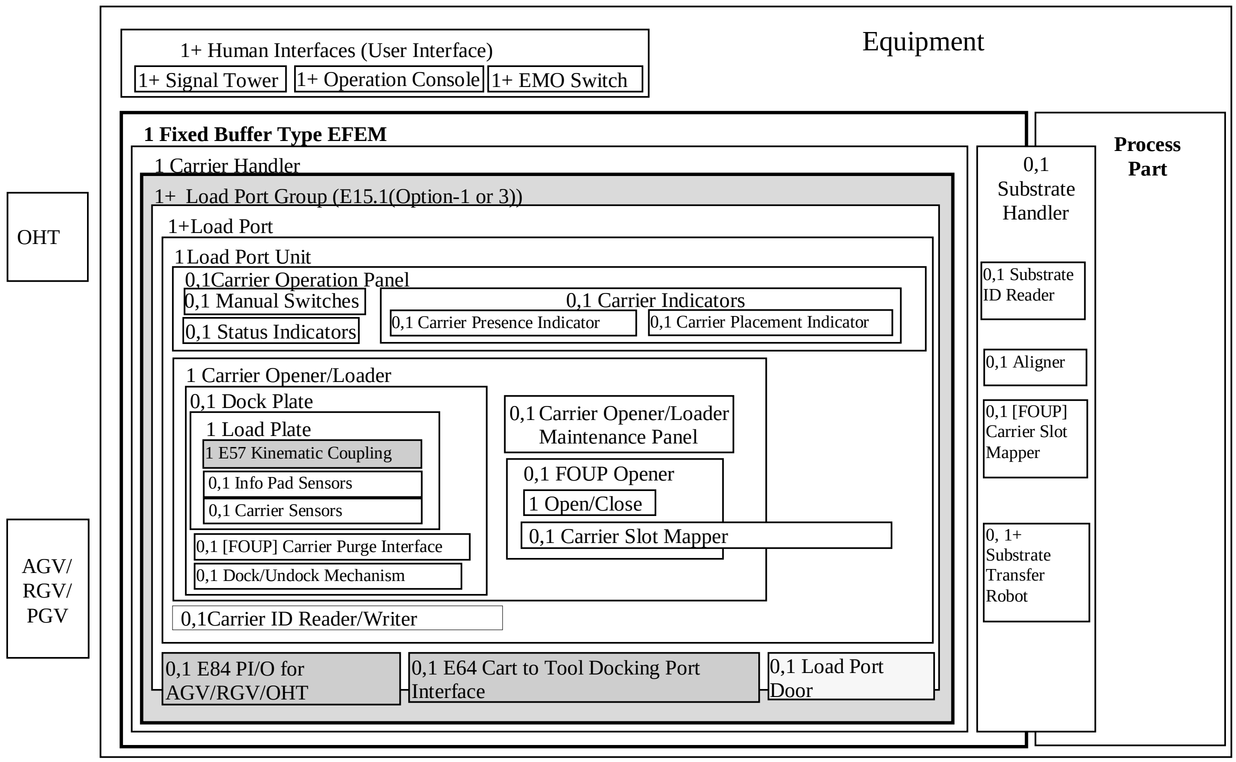


**Figure A1-1**
**Relation between Fixed Buffer Type EFEM Functional Structure Model and Existing SEMI Standards**

# APPENDIX 2

**NOTICE**: The material in this appendix is an official part of SEMI E101 and was approved by full letter ballot procedures on January 14, 2000 by the Japanese Regional Standards Committee.

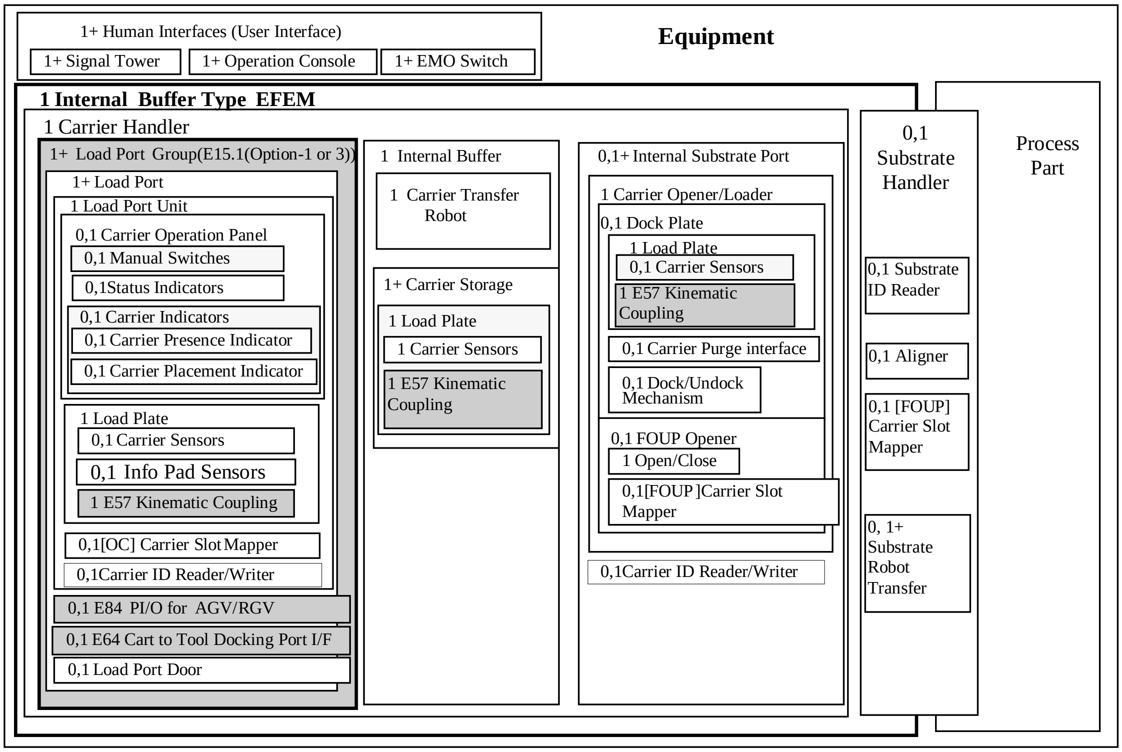


**Figure A2-1**
**Relation between Internal Buffer Type EFEM Functional Structure Model and Existing SEMI Standards**

# SEMI E103-0704
# MECHANICAL SPECIFICATION FOR A 300 mm SINGLE-WAFER BOX SYSTEM THAT EMULATES A FOUP

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 May 14, 2004. Initially available at www.semi.org June 2004; to be published July 2004. Originally published June 2000; last published November 2003.

## 1 Purpose

1.1 This standard specifies the carrier side of the mechanical interface between load ports (or buffers) with FIMS interfaces on process or metrology equipment and a system that includes a box that holds only one wafer (such as a test wafer) and that fits onto an adapter mechanism called a single-wafer interface (SWIF). This system appears to the equipment to be a 300 mm FOUP (except that only the volume around the middle wafer may be accessible).

## 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 inter-changeability at relevant mechanical interfaces. Only the mechanical interface between a load port with a FIMS interface and this system (of a single-wafer box and a SWIF) is specified here; the mechanical interface between the single-wafer box and the SWIF is not specified. Also not specified is the method by which the SWIF raises the carrier sensing pads when the single-wafer box is removed (see Section 6.3). This standard does not forbid the SWIF from holding more than just the single-wafer box mentioned in this standard.

**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 E19 — Standard Mechanical Interface (SMIF)

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

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

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

## 4 Ordering Information

4.1 *Info Pad Configuration* — The purchaser of a single wafer interface system needs to specify the desired info pad configuration (up or down).

## 5 Terminology

5.1 *Abbreviations & Acronyms*

5.1.1 *FOUP* — front-opening unified pod

5.1.2 *PGV* — person guided vehicle (cart)

5.1.3 *SWIF* — single-wafer interface

5.2 *Definitions*

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

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

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

5.2.4 *front-opening unified pod* — 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) (as defined in SEMI E47.1).

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

5.2.6 *single-wafer interface* — an adapter mechanism that holds a single-wafer box and that appears to the equipment to be a 300 mm FOUP (except that only the volume around the middle wafer may be accessible).

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

## 6 Requirements

6.1 *System Components* — A system that conforms to this standard must include a box that holds one wafer and that fits onto a SWIF.

6.2 *Relevant FOUP Dimensions* — The SWIF must have all of the required bottom and front features and be no larger than the maximum dimensions of a 13- or 25-wafer FOUP. However, this system (of single-wafer box and SWIF) must have box placement sensing pads as specified in SEMI E47.1 FOUP standards Requirements Section 6.12. For example, the SWIF must comply with dimensions r67, x53, y50, y51, y52, y53, z41, z47 – z48, z47 + z49, and the upper limits on x50 and y40 (as specified in SEMI E47.1) and with dimension y33 (as specified in SEMI E62).

6.3 *Optional Automation Features* — Since the single-wafer box and/or SWIF will usually be delivered manually (possibly with a PGV), the SWIF is not required to have the other automation features of the FOUP such as the robotic handling flange on top or the fork-lift flanges on the side (although this standard does not forbid the SWIF from having such features).

6.4 *SWIF Door* — The SWIF must have a full FOUP-size door (which surrounds the door of the single-wafer box) that mates with a FIMS-compatible interface (as specified in SEMI E62) to avoid contaminating the environment on the equipment side of the FIMS interface.

6.5 *Wafer Position* — When the FIMS door is opened by the equipment, the end effector may only be able to access the middle wafer slot (wafer 7 for a SWIF that emulates a 13-wafer carrier, and wafer 13 for a SWIF that emulates a 25-wafer carrier), because a surface immediately behind the door may block access to the other wafer slots. Thus, batch wafer handlers will probably not work with this system.

6.6 *Wafer Clearances* — The clearance below the middle wafer must be the same as the clearance below the bottom wafer in an ordinary FOUP (z8 minus z6, both from SEMI E1.9), and the clearance above the middle wafer must be the same as the clearance above the top wafer in an ordinary FOUP (z15 from SEMI E1.9). These vertical clearances are defined in SEMI E1.9 and SEMI E47.1 and apply throughout the wafer set-down and extraction volumes for the middle wafer. The horizontal clearances shown in Figure 10 of SEMI E47.1 are also required. One possible example of such a system (of single-wafer box and SWIF) is shown in Figures 1 and 2 (with vertical clearances indicated).

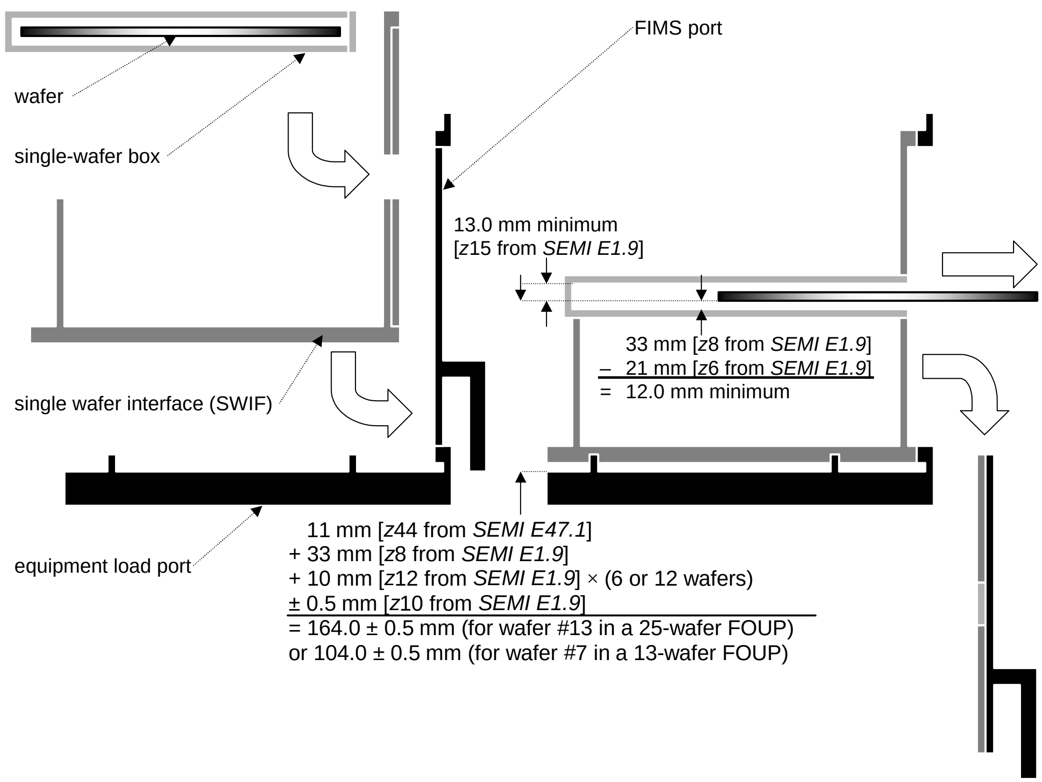


**Figure 1**
**Side View of Example Single-Wafer Box and SWIF on a Load Port with a FIMS Interface**

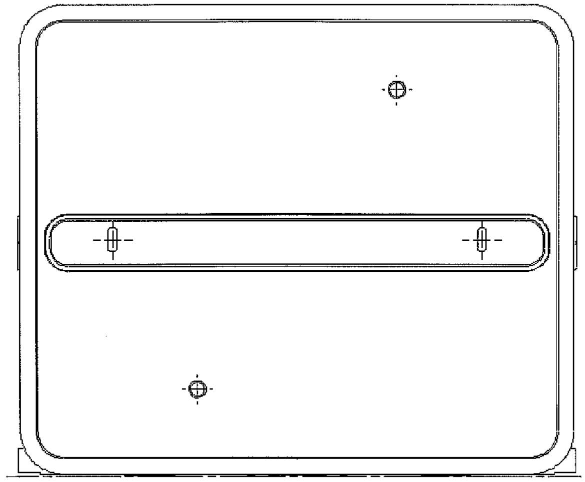

**Figure 2**
**Front View of Example Single-Wafer Box and SWIF**

6.7 *SWIF Sensing* — It is possible that the SWIF is not removed from the load port when single-wafer boxes are removed and replaced on the SWIF. However, when the single-wafer box is removed from the SWIF, all of the carrier sensing pads (defined in Section 6.6 of SEMI E1.9) on the bottom of the SWIF must be raised (so that the load port can sense a change of carriers by its carrier placement sensor, if any). However, in order to ensure that the SWIF triggers most optical carrier presence detectors on the load port, the SWIF (without a single-wafer box) must block any line of sight through a volume consisting of the smallest cylindrical section that contains all of the wafer pick-up volumes (defined in SEMI E1.9) of the corresponding FOUP (defined in SEMI E47.1). Note that this standard does not prevent the use of other kinds of carrier presence detectors (such as sensors that detect weight on the load port).

## 7 Related Documents

7.1 *SEMI Standards*

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

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

SEMI E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E72 — Specification and Guide for 300 mm Equipment Footprint, Height, and Weight

SEMI E92 — Specification for 300 mm Light Weight and Compact Box Opener/Loader and Tool-Interface Standard (BOLTS-Light)

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

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

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

# RELATED INFORMATION 1
# APPLICATION NOTES

**NOTICE**: This related information is not an official part of SEMI E103 but was approved for publication by full letter ballot procedures on July 28, 2000.

## R1-1

R1-1.1 In fabs in which this system (of single-wafer box and SWIF) is used, equipment should have control software algorithms that prevent end effectors and wafer slot mappers from entering the carrier except in the clearances around the middle wafer (defined in Section 6.2) when the presence of this system is detected. A variety of methods for differentiating the system from ordinary FOUPs are possible.

R1-1.2 Using sensors, equipment can differentiate the system (of single-wafer box and SWIF) from ordinary FOUPs. For example, sensors below the info pad B location on the load port and on the FIMS door (opposite the seal zones or the reserved spaces for vacuum application on the box door) could indicate that the carrier type is an open cassette but with a FOUP door, together implying the presence of this system (of a single-wafer box and SWIF). Note that such sensors on the load port are not currently specified in any SEMI standard.

R1-1.3 Carrier ID tags can inform the equipment that the load port holds this system (of single-wafer box and SWIF) instead of an ordinary FOUP.

R1-1.4 Messages from the host computer system can inform the equipment that the load port holds this system (of single-wafer box and SWIF) instead of an ordinary FOUP.

# SEMI E104-0303
# SPECIFICATION FOR INTEGRATION AND GUIDELINE FOR CALIBRATION OF LOW-PRESSURE PARTICLE MONITOR

This specification 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 January 8, 2003. Initially available at www.semi.org January 2003; to be published March 2003. Originally published October 2000; previously published March 2002.

## 1 Purpose

1.1 The use of *in situ* particle monitoring (ISPM; particle measurements performed while the wafer resides inside the processing chamber) in low-pressure and vacuum applications provides a number of advantages for defect, process, and equipment management such as:

- Reduction of particle test wafers used for off-line tests and saving operator time,
- Optimization and real-time characterization of the process,
- Advanced process control,
- Advanced equipment control,
- Monitoring process chamber conditions, and
- Optimization of cleaning procedures and maintenance.

1.1.1 Therefore, ISPM achieves more equipment availability and faster ramp-up of the production, reduces cost of ownership, improves quality and yield. To reach these goals, ISPM needs to be easily integrated into new or existing process equipment and the acquisition as well as the analysis of the particle data needs to be automated. The ISPM sensor should not have any negative influence on the process and the measurement has to represent the main particle flow. The sensor should be designed to have a minimum negative impact on the parameters defined in SEMI E10 for the whole semiconductor process equipment, to achieve an advantage in capacity.

1.2 This standard is intended to stipulate operating conditions, mechanical, electrical, and communication interfaces for the use of Low-pressure Particle Detectors integrated in semiconductor process equipment. A guideline for a reference calibration of those sensors is intended to support correlation between measurements with different sensors.

## 2 Scope

2.1 This standard applies to particle measurement under low-pressure and vacuum conditions in semiconductor manufacturing equipment.

**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 health practices and determine the applicability of regulatory or other limitations prior to use.

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI C6.5 — Particle Specification for Grade 10/0.2 Nitrogen ($N_2$) and Argon (Ar) Delivered as Pipeline Gas

SEMI C6.6 — Particle Specification for Grade 10/0.1 Nitrogen ($N_2$) and Argon (Ar) Delivered as Pipeline Gas

SEMI E4 — SEMI Equipment Communications Standard 1 Message Transfer (SECS-I)

SEMI E5 — SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E33 — Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

SEMI E37 — High-Speed SECS Message Services (HSMS) Generic Services

SEMI E54 — Sensor/Actuator Network Standard

SEMI E54.10 — Specification for Sensor/Actuator Network Specific Device Model for an In-Situ Particle Monitor Device

SEMI F6 — Guide for Secondary Containment of Hazardous Gas Piping Systems

3.2 *ASTM Standards*[1]

ASTM D1193 — Standard Specification for Reagent Water

ASTM F328 — Standard Practice for Calibration of an Airborne Particle Counter Using Monodisperse Spherical Particles

ASTM F649 — Practice for Secondary Calibration of Airborne Particle Counter Using Comparison Procedures

3.3 *BSI Standards*[2]

BS 3406-7 — Determination of Particle Size Distribution – Recommendations for Single Particle Light Interaction Methods

3.4 *IEC Standards*[3]

IEC 60625-1 — Programmable Measuring Instruments - Interface System (Byte Serial, Bit Parallel) - Part 1: Functional, Electrical and Mechanical Specifications, System Applications, and Requirements for the Designer and User

IEC 60625-2 — Programmable Measuring Instruments - Interface System (Byte Serial, Bit Parallel) - Part 2: Codes, Formats, Protocols, and Common Commands

IEC 60654-1 — Operating Conditions for Industrial-Process Measurement and Control Equipment - Part 1: Climatic Conditions

IEC 60654-2 — Operating Conditions for Industrial-Process Measurement and Control Equipment - Part 2: Power

IEC 60654-3 — Operating Conditions for Industrial-Process Measurement and Control Equipment - Part 3: Mechanical Influences

IEC 60654-4 — Operating Conditions for Industrial-Process Measurement and Control Equipment - Part 4: Corrosive And Erosive Influences

IEC 60801-1 — Electromagnetic Compatibility for Industrial-Process Measurement and Control Equipment - Part 1: General Introduction

3.5 *IEEE Standards*[4]

IEEE 488.1 — IEEE Standard Digital Interface for Programmable Instrumentation

IEEE 488.2 — IEEE Standard Codes, Formats, Protocols, and Common Commands for use with IEEE 488.1, IEEE Standard Digital Interface for Programmable Instrumentation

3.6 *IEST Standards*[5]

IEST RP-011 — A Glossary of Terms and Definitions Related to Contamination Control

3.7 *ISO Standards*[6]

ISO 1609 — Vacuum technology -- Dimensions (ISO-K style and ISO-F style)

ISO 2861-1 — Vacuum technology -- Quick-release couplings – Dimensions - Part 1: Clamped type (ISO-KF)

ISO 2861-2 — Vacuum technology -- Quick-release couplings – Dimensions - Part 2: Screwed type (ISO-MF)

ISO 3669 — Vacuum technology -- Bakeable flanges -- Dimensions (ISO-K-CF)

ISO 10012-1 — Quality assurance requirements for measuring equipment – Part 1: Metrological confirmation system for measuring equipment

ISO 10012-2 — Quality assurance requirements for measuring equipment – Part 2: Guidelines for control of measuring processes

ISO 13323-2 — Determination of particle size distribution – Single Particle Light Interaction Methods Part 2: Light scattering single particle light interaction devices design, performance specifications, and operation requirements

ISO 14644-1 — Cleanrooms and associated controlled environments - Part 1: Classification of air cleanliness

ISO 14644-5 — Cleanrooms and associated controlled environments - Part 5: Operation of cleanroom systems

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959, USA. Telephone: 610.832.9585, Fax: 610.832.9555 Website: www.astm.org

2 British Standards Institute, 389 Chiswick High Road, London, W4 4AL, United Kingdom. Telephone: 44.0.20.8996.9000, Fax: 44.0.20.8996.7001 Website: www.bsi-global.com

3 International Electrotechnical Commission, 3, rue de Varembé, Case Postale 131, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.919.02.11; Fax: 41.22.919.03.00 Website: www.iec.ch

4 Institute of Electrical and Electronics Engineers, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, USA. Telephone: 732.981.0060; Fax: 732.981.1721

5 Institute of Environmental Sciences and Technology, 5005 Newport Drive, Suite 506, Rolling Meadows, IL 60008-3841, USA. Telephone: 847.255.1561; Fax: 847.255.1699 Website: www.iest.org

6 International Organization for Standardization, ISO Central Secretariat, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland. Telephone: 41.22.749.01.11; Fax: 41.22.733.34.30 Website: www.iso.ch

3.8 *JIS Standards*[7]

JIS B 9921 — Light Scattering Automatic Particle Counter

3.9 *VDI Standards*[8]

VDI-Richtlinie 3489-3 — Messen von Partikeln: Methoden zur Charakterisierung und Überwachung von Prüfaerosolen - Optischer Partikelzähler (Particulate Matter Measurement: Methods of Characterizing and Monitoring Test Aerosols – Optical Particle Counter)

VDI-Richtlinie 3491 — Messen von Partikeln: Herstellungsverfahren für Prüfaerosole, Verdünnungssysteme (Particulate Matter Measurement: Generation of Test Aerosols, Dilution Systems)

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

## 4 Terminology

4.1 *Abbreviations and Acronyms*

4.1.1 COV — Coefficient of Variation

4.1.2 HEPA — High-Efficiency Particulate Air

4.1.3 ISPM — In Situ Particle Monitor

4.1.4 LDL — Lower Detectable Limit

4.1.5 LPPD — Low-Pressure Particle Detector

4.1.6 PHA — Pulse Height Analyzer

4.1.7 RPC — Reference Particle Counter

4.1.8 ULPA — Ultra-Low Penetration Air

4.2 *Definitions*

4.2.1 *accuracy of size* — the closeness of agreement between the ascertained size of the detected particle and its real size.

4.2.2 *coefficient of variation (COV)* — the width of a distribution (in %), obtained by dividing the standard deviation of the distribution by the mean of the distribution.

4.2.3 *coincidence* — the presence of two or more particles in the detection area of the particle detector at the same time, causing the particle detector to interpret the combined signal erroneously as resulting from one larger particle.

4.2.4 *concentration* — the number of particles per unit volume, at ambient temperature $T_A$ and pressure p.

4.2.5 *concentration limit* — the particle concentration specified by the manufacturer of the particle detector at which the error due to coincidence is 10% or less.

NOTE 1: Manufacturers may specify concentration limits at error levels other than 10%.

4.2.6 *counting efficiency* — the ratio (in %) of detected concentration divided by the actual concentration of particles of a given size or range of sizes (see appendix 2).

4.2.7 *detection area* — the area, defined through the light beam and the detection optics, in which the particles are detected. Often this area is much smaller than the cross-section of the pump line or the process chamber.

4.2.8 *high-efficiency particulate air (HEPA) filter* — filter with a minimum particle-collection efficiency of 99.97% on all particles larger than 0.3 micrometer.

4.2.9 *in situ* — refers to processing steps or tests that are done without moving the wafer. Latin for “in original position”.

4.2.10 *in situ particle monitor (ISPM)* — particle monitor used under atmospheric conditions or in low-pressure, vacuum or liquid applications to detect particles while a process is running.

4.2.11 *isokinetic sampling* — sampling of particles in a moving aerosol or fluid by matching the sample probe inlet velocity (flow speed and direction) to the velocity of the moving aerosol or fluid.

4.2.12 *lower detectable limit (LDL)* — in particle measurement: the smallest particle size that a particle detector can measure at a given flow rate with a signal-to-noise ratio of at least 3 dB and with a counting efficiency of 50% ± 10%.

NOTE 2: This is a general definition of LDL. Due to the special design of most of the LPPDs, a counting efficiency of 50% can not be achieved.

4.2.13 *low-pressure particle detector (LPPD)* — optical particle sensor for use under low-pressure and vacuum conditions to measure particles or particle levels in semiconductor process equipment.

4.2.14 *monodisperse calibration particles* — particles with known optical properties, a sizing accuracy of at least 95%, and a size distribution in which the coefficient of variation is 5% or less.

4.2.15 *optical equivalent size* — the diameter of a monodisperse calibration particle that produces the

7 Japanese Industrial Standards, Available through the Japanese Standards Association, 1-24, Akasaka 4-Chome, Minato-ku, Tokyo 107-8440, Japan. Telephone: 81.3.3583.8005; Fax: 81.3.3586.2014 Website: www.jsa.or.jp

8 Beuth Verlag GmbH, Burggrafenstrasse 6, D-10787 Berlin, Germany. Telephone: 49.30.2601.0, Fax: 49.30.2601.1260 Website: www2.beuth.de

same detected scattering intensity as the localized light scatterer (LLS) under investigation under identical test conditions.

4.2.16 *particle size* — for applications, size is the optical equivalent diameter of a reference sphere with known properties as detected by a given light-scattering particle counter [as defined in SEMI C6.5 and SEMI C6.6]. For calibration, size is the mean diameter of the monodisperse sphere.

4.2.17 *resolution* — the capability of the particle detector to differentiate between particles of similar size.

NOTE 3: The procedure to define resolution is discussed in Section 9.2.3.5.

4.2.18 *sensitivity* — in particle measurement: the smallest standard particle size specified by the manufacturer that an instrument, method, or system is capable of measuring under specified conditions (with a counting efficiency of 50%; see Appendix 2). Also called minimum detectable particle size.

4.2.19 *ultrafine particle* — a particle with an equivalent diameter less than 0.1 µm [as defined in ISO 14644-1].

4.2.20 *ultra-low penetration air (ULPA) filter* — filter with a minimum particle-collection efficiency of 99.9995% on the most penetrating particle size.

4.2.21 *zero count* — the maximum particle count indicated by a particle counter, in a specified period of time, that is sampling particle-free air. This value is specified by the manufacturer, and is commonly also referred to as false call rate, false count, noise, or noise level.

4.2.22 *zero gas* — in determining contaminant contribution by gas distribution system components, a purified gas that has an insignificant particle concentration above the lower detectable limit (LDL) of the analytical instrument. This gas is used for both instrument calibration and component testing.

4.3 *Symbols*

4.3.1 $A_L$ — the detection area (mm$^2$), defined through detector optics and light beam of the LPPD.

4.3.2 $A_{RC}$ — the opening area (mm$^2$) of the probe inlet of the reference particle counter.

4.3.3 $C_L$ — the number concentration (cm$^{-3}$) of particles in the line at the LPPD.

4.3.4 $C_G$ — the number concentration (cm$^{-3}$) of particles generated from aerosol generator at given $V'_G$.

4.3.5 $D_L$ — the diameter of the pump line (mm) at the LPPD.

4.3.6 $d_p$ — the diameter of the spherical particle (µm).

4.3.7 $D_{RC}$ — the diameter of the sample drawing line (mm) for the reference particle counter.

4.3.8 $D_{VM}$ — the diameter of the pump line (mm) at the velocity meter.

4.3.9 p — the line pressure (torr or mbar).

4.3.10 RH — the relative humidity (%).

4.3.11 $T_A$ — the ambient temperature (° C) around the measurement or calibration system.

4.3.12 $T_G$ — the gas temperature (° C).

4.3.13 $v_L$ — the velocity (m/s) of the aerosol at the LPPD.

4.3.14 $v_{L,\ min}$, $v_{L,\ max}$ — for applications, the velocity range (m/s) of the aerosol at the LPPD specified by the manufacturer.

4.3.15 $V'_L$ — the volume flow rate (l/min) in the line at the LPPD.

4.3.16 $V'_G$ — the volume flow rate (l/min) of the aerosol sample (measured directly behind the aerosol generator).

4.3.17 $v_{VM}$ — the velocity (m/s) of the aerosol at the velocity meter.

4.3.18 $V'_{ZG}$ — the volume flow rate (l/min) of the zero gas.

4.3.19 $\sigma_{V,LPPD}$ — the standard deviation of the voltage sensor signal.

4.3.20 $\sigma_{p,LPPD}$ — the standard deviation of the observed particle distribution

4.3.21 $\sigma_{d,p}$ — the standard deviation of the particles given by the particle supplier

## 5 Mechanical Interfaces

5.1 *Flanges*

5.1.1 One of the following vacuum flanges should be used for mounting an LPPD into a pump line or on process equipment:

ISO 2861-1 and ISO 2861-2 (ISO-KF/MF)

ISO 1609 (ISO-K and ISO-F)

ISO 3669 (ISO-K-CF)

5.2 *Space, Distances, and Installation*

5.2.1 The use of an LPPD should not have a negative impact on the process performance. The sensor location in the equipment shall ensure an optimum use of the sensor sensitivity in order to allow a measurement which is representative of the main particle flow. The influence of the process and the process equipment on the LPPD shall be minimized (thermal background radiation, vibrations etc.)

5.2.2 The standard does not specify where an LPPD should be located in original equipment, or where space should be allowed for retro-fitting. It is recognized that the location is dependent on factors including transport behavior of particles, thermal background radiation etc. The designers of semiconductor process equipment should resort to the experience of application engineers of the LPPD suppliers and the end users. However, in either case designers shall take into account access requirements for maintenance and re-calibration. In the case of retro-fitting, the design should facilitate sensor installation rather than hinder it.

## 6 Electrical Interfaces

6.1 *Sensor/Controller Communication*

6.1.1 Depending on the choice of the LPPD supplier and the semiconductor equipment manufacturer, one of the following interfaces for data exchange between the LPPD and process equipment controller should be used.

6.1.2 *Sensor/Actuator Network (SAN)*

6.1.2.1 The electrical interfaces of the Sensor/ Actuator Network are described in the suite of SEMI E54 standards.

6.1.3 *Serial Communication*

6.1.3.1 RS 232 C (V.24/V.28)

6.1.3.2 RS 485

6.1.4 *Others*

6.1.4.1 IEEE 488 or IEC 60625

6.2 *Others*

6.2.1 *Sensor calibration output (direct analog output)*

6.2.1.1 The analog output for access to the sensor signal used for calibration purpose should be supported.

## 7 Communication Interfaces

7.1 *Sensor Bus Communication*

7.1.1 It is recommended to use a Sensor/Actuator Network (SAN) for the intra-tool communication between the LPPD controller and the controller of the process equipment. This communication is based on a suite of SEMI standards including a network communication standard, several common device models (DeviceNet, SDS, Lonworks, ProfiBus etc.), and the specific device model for the sensor. The Network is described by the following suite of SEMI standards: SEMI E54. The specific device model for ISPM is described by SEMI E54.10.

7.2 *SEMI Equipment Communication (SECS)*

7.2.1 If LPPD controllers provide the collected particle data to the process equipment controller, factory automation system, or SPC system, the SECS tool-to-host communication could be used. SECS is described in the following standards:

- SEMI E5
- SEMI E4
- SEMI E37

7.3 *Attribute Definitions*

7.3.1 SEMI E54.10 addresses the minimum attributes, services and behavior an ISPM-device shall support. If any attributes and services are used by communication of the ISPM and the equipment controller via IEEE 488 (IEC 60625) or serial communication, they should be concurring.

## 8 Operating Conditions

8.1 To specify the operating conditions of an LPPD (temperature, humidity, electromagnetic compatibility, vibrations etc.) refer to the following standards:

- IEC 60654-1
- IEC 60654-2
- IEC 60654-3
- IEC 60654-4
- IEC 60801-1

8.2 *Temperature*

8.2.1 The LPPD should work correctly at an ambient temperature range $T_A$ as specified in ISO 14644-5. If the use of an LPPD at an extended ambient temperature range is required, the specific LPPD should comply with these conditions.

8.2.2 The temperature $T_G$ inside the pump line or inside the process equipment depends on the actual application. The application engineers shall check the use of LPPDs under these specific conditions. The temperature $T_G$ is measured at the flange which the LPPD is mounted on.

8.3 *Humidity*

8.3.1 The LPPD should work correctly at an ambient humidity range RH as specified in ISO 14644-5. If the use of an LPPD at an extended ambient humidity range is required, the specific LPPD should comply with these conditions.

8.4 *Electromagnetic Compatibility*

8.4.1 The equipment should comply with SEMI E33.

8.4.2 Sensors will be incorporated into equipment either as original equipment or retro-fitted. In either case, the sensors or the equipment of which they are a part should comply with the current regulations covering EMC in the country or region where the equipment or sensor is used.

8.5 *Vibrations*

8.5.1 Process equipment designers are advised to consider the impact of vibration on the performance of the sensor while it is collecting data. Therefore, they should minimize vibrations. The designers of the LPPD sensors are also advised to consider the impact of vibrations on the equipment at a time the sensor is not collecting any data. It might be possible that these vibrations are stronger than those occurring while the sensor is collecting data.

## 9 Reference Calibration Procedure

9.1 The response of real contamination particles, typically with refractive indices and shapes different from calibration particles, will differ slightly from the results obtained by the procedures in this document. It is known that LPPDs with different optical design may not produce the same data from identical aerosol samples. This may happen even with similar LPPDs if calibration differences have occurred. Therefore, before the first use the sensor should be calibrated by the manufacturer. This calibration should be compliant with or should be reviewed with the following reference calibration equipment and procedure. This reference calibration allows the characterization of the performance of the LPPD under test. The LPPD should be recalibrated at regular intervals and also in case of unusual measurement readings to ensure correct results.

9.1.1 The parameters calibrated for LPPDs with sizing capability are:

- Sizing calibration,
- Resolution,
- Zero counting,
- Counting efficiency, and
- Sensitivity.

9.1.2 The parameters calibrated for LPPDs with non-sizing capability are:

- Zero counting, and
- Counting efficiency.

9.1.3 Field calibration may not necessarily require the calibration of all parameters performed by calibration at the sensor manufacturers site.

9.1.4 Due to the fact that different LPPDs might be working with different detection areas $A_L$, the number of counts should be printed out in counts per $mm^2$ detection area. Therefore, a comparison of the measurement results of different LPPDs is possible. The size of the detection area $A_L$ shall be reported in the calibration report form. Any changes of calibration parameters or of the calibration setup shall be reported in the calibration report form. A copy of the calibration report form shall be delivered with the sensor.

9.2 *Apparatus*

9.2.1 *Materials*

9.2.1.1 *Particles*

9.2.1.1.1 Calibration particles are polymer spheres composed of polystyrene or a similar polymer, having a refractive index of 1.58-1.61+ 0i (absorption coefficient $\alpha$ = 0), a sizing accuracy of at least 95%, and a size distribution in which the coefficient of variation is 5% or less. They should be traceable to a nationally or internationally recognized standard (e.g. NIST[9]).

9.2.1.1.2 The calibration particles are normally supplied in concentrations too high to be used directly in aerosol generators. The particles should be dispersed and diluted in either deionized, distilled water in accordance with ASTM D1193, Type 1, or Isopropanol. The diluent should be cleaned using a filter with a pore size no more than 10% of the size of the particles being used. The solution should be stored in a clean container. For generation and dilution of the suspension see Appendix 3. After generation the particles should be neutralized to avoid surface charge. For all tests described in this document, the concentration should be no more than 25% of the maximum recommended concentration limit specified by the manufacturer. For calibration a suitable set of particle sizes shall be used. This set should contain at least 5 sizes that cover the LDL size to at least 80% of the specified maximum size measurement capability of the LPPD.

NOTE 4: Most of the ISPM sensors are based on light scattering. The intensity of the scattered light detected by a photodetector depends on intensity, polarization state, and

9 National Institute of Standards and Technology, 100 Bureau Drive, Gaithersburg, MD 20899-0001, USA

wavelength of the incident light beam, diameter, shape, and refractive index of the particle and the suspension fluid, as well as on the geometrical layout of the collection optics and detector. In the particle size range near the wavelength ($0.1\lambda < d_P < 10\lambda$), large oscillations can be seen in the intensity curve of the light scattered by spherical particles as a function of all these parameters. This phenomenon should be taken into account when selecting a suitable set of particle sizes for calibration. The used calibration particles should be within a monotonic response range of the LPPD response curve.

9.2.1.2 *Zero Gas*

9.2.1.2.1 Clean air or nitrogen filtered with a ULPA filter.

NOTE 5: The calibration will be executed under atmospheric pressure and zero gas. In semiconductor manufacturing, pressure and process gases will differ from the calibration conditions. This will affect the refractive index ratio of the particles and the process gas and consequently the scattering from the particles.

9.2.1.3 *Surfaces*

9.2.1.3.1 The materials of pump lines and other components should be conductive to minimize electrostatic interaction with the particles.

9.2.2 *Instrumentation (see Figure 1)* — Some LPPDs may require specialized equipment not generally available. Please contact the LPPD manufacturer.

9.2.2.1 *Fan System*

9.2.2.1.1 The fan or pump system should be adjustable to transport the aerosol and the zero gas within the stipulated velocity range $v_{L,\ min}$ ... $v_{L,max}$, specified by the manufacturer of the LPPD.

9.2.2.2 *Filter System*

9.2.2.2.1 The ULPA filter system is used for generation of zero gas. The filter system should be capable of removing particles at the minimum size detectable by the LPPD or the reference particle counter.

9.2.2.3 *Aerosol Generator*

9.2.2.3.1 An atomizer converts the monodisperse particle suspension to an aerosol by using compressed zero gas for generation and transportation of the particles. The aerosol generator should generate monodisperse particles as defined in Section 9.2.1.1 in constant and reproducible concentration $C_G$ under constant and reproducible volume flow rate $V'_G$. The variation in particle concentration shall be no more than 10% as measured by the reference particle counter over a time period of 10 times or more of the sample measurement time. The generation should comply with the German VDI-Richtlinie 3491, or an equivalent standard in other countries.

9.2.2.4 *Aerosol dryer*

9.2.2.4.1 The monodisperse polymer spheres in the test aerosol shall be thoroughly dry to avoid that the particles have a water layer which would increase their size. A diffusion dryer, another appropriate instrument, or adequately dry dilution air should be used to dry the particles. The diffusion dryer uses silica gel desiccant to remove the moisture. The desiccant shall either be new or freshly regenerated. The design flow rate of the aerosol dryer shall at least match the output flow rate of the aerosol generator.

NOTE 6: Some diffusion dryers may precipitate polymer spheres and add other particles when the aerosol gets in direct contact with the silica gel.

9.2.2.5 *Neutralizer*

9.2.2.5.1 An aerosol neutralizer should be connected in line with the dryer to reduce electrostatic charges on the dry polymer spheres and to avoid electrostatic interaction with each other or the line wall. The design flow rate of the aerosol neutralizer shall at least match the output flow rate of the aerosol generator.

NOTE 7: Some electrostatic neutralizers may produce a large number of ultra-fine particles which will combine with the calibration aerosol.

9.2.2.6 *Aerosol Size Separator*

9.2.2.6.1 In the case of calibration with ultra-fine particles, a system should be used to separate single polymer spheres from the residual particles resulting from vaporization of solutions and aggregate particles consisting of several spheres. The size separation could be achieved with an electrostatic classifier or a diffusion battery.

9.2.2.7 *Aerosol Dilution*

9.2.2.7.1 If the particle concentration behind the aerosol generator is too high, the particle flow shall be diluted to achieve the required concentration and to avoid coincidence errors. The dilution should comply with the German VDI-Richtlinie 3491, or an equivalent standard in other countries.

9.2.2.8 *Aerosol Line System*

9.2.2.8.1 The system consisting of

- the aerosol generator,
- the aerosol dryer,
- the neutralizer,
- the particle size separator,
- the dilution stage, and
- tubing connecting the devices with each other and the filtered, dried and compressed zero gas.

9.2.2.8.2 The line system should be smooth, conductive, and electrically grounded to minimize electrostatic interaction of the particles with line walls and the particles themselves. The line should be as short and straight as possible with no bends with a radius of curvature less than 100 mm. Leak-free connections of the line and all devices should be ensured using appropriate fittings.

9.2.2.8.3 Figure 1 illustrates a recommended calibration aerosol generation system.

9.2.2.9 *Flow Control*

9.2.2.9.1 The velocity of aerosol and the zero gas should be within the stipulated range $v_{L,\ min}$ ... $v_{L,max}$, specified by the manufacturer of the LPPD. Dependent on the line diameter $D_L$, a stipulated aerosol flow is necessary. The velocity meter (e.g. thermoanemometer) or flow meter should be mounted in a line with known diameter $D_{VM}$.

NOTE 8: The aerosol drawn by the reference particle counter influences the velocity or flow measured by the velocity meter or flow meter if it is mounted behind the probe inlet. This is taken into account when calculating and adjusting the flow and velocity $v_L$ at the LPPD. If the velocity meter or flow meter is mounted in front of the probe inlet of the reference particle counter, the device should have no influence on the particle size distribution measured by the reference particle counter.

9.2.2.10 *Calibration Line System*

9.2.2.10.1 The system consisting of

- a device to inject the particles into the zero gas,
- a device to mix the aerosol sample with the zero gas to obtain uniform particle concentration,
- a device to adapt the LPPD into the line (diameter $D_L$),
- a device to adapt the velocity meter or the flow meter,
- a device (diameter $D_{RC} = D_L$, same particle concentration as at the LPPD) to draw a defined, isokinetic sample from the line for the reference particle counter (the opening area of the probe inlet should be reported in the calibration report form), and
- tubing connecting the devices with each other and with the fan and filter system.

9.2.2.10.2 The line system should be smooth, conductive, and electrically grounded to minimize electrostatic interaction of the particles with line walls and the particles themselves. The line should be as short and straight as possible with no bends with a radius of curvature less than 100 mm. Leak-free connections of the line and all devices should be ensured using appropriate fittings.

9.2.2.10.3 Figure 1 illustrates a recommended LPPD calibration system.

NOTE 9: The distance between the device to adapt the LPPD under test and the device for sample acquisition for the reference particle counter should be as short as possible to minimize particle loss and to ensure comparable particle concentrations.

9.2.2.11 *Reference Particle Counter (RPC)*

9.2.2.11.1 The reference particle counter is required to measure the actual concentration of the monodisperse aerosol and the quality of the zero gas inside the line. Therefore, the counting efficiency of the reference particle counter is defined as 100% over the range of particle sizes used in the test. The resolution should be better than 10% at the lower detection limit of the LPPD under test. The values of the measurement should be printed out in counts per $mm^2$ opening area $A_{RC}$ of the probe inlet. The sample transit line from the probe inlet and the reference particle counter should be as short and as straight as possible. Smooth, conductive, and electrically grounded materials should be used.

9.2.2.12 *Sensor Window Temperature*

9.2.2.12.1 Some LPPDs have the capability to heat their sensor windows to avoid coating of the window. A device to measure and to adjust the sensor window temperature within the operating range (measurable to 5%) should be installed in the calibration setup. The thermometer should be calibrated with an accuracy of 0.2° C.

9.2.2.13 *Pulse Height Analyzer (PHA)*

9.2.2.13.1 The external analyzer is connected with the analog sensor calibration output. The PHA should have at least 64 channels and a resolution of at least 1% of the average voltage that will be measured. The use of a PHA, which is built into the sensor electronics, is allowed if this PHA meets the criteria mentioned above. The required range and speed will depend on the performance of the LPPD under test. These parameters should be obtained by the LPPD manufacturer.

9.2.2.14 *Environmental Monitoring*

9.2.2.14.1 The environmental temperature $T_A$ is measured by a thermometer calibrated with an accuracy of 0.2° C.

9.2.2.14.2 The environmental relative humidity RH is measured by a hygrometer.

9.2.2.14.3 The atmospheric pressure p is measured by a barometer calibrated with an accuracy of 133 Pa.

9.2.2.15 All instruments used for the reference calibration procedure shall have been checked for valid calibration in accordance with ISO 10012-1 and 10012-2. Record all calibration data.

9.2.3 *Setup and Schematic*

9.2.3.1 See Figure 1.

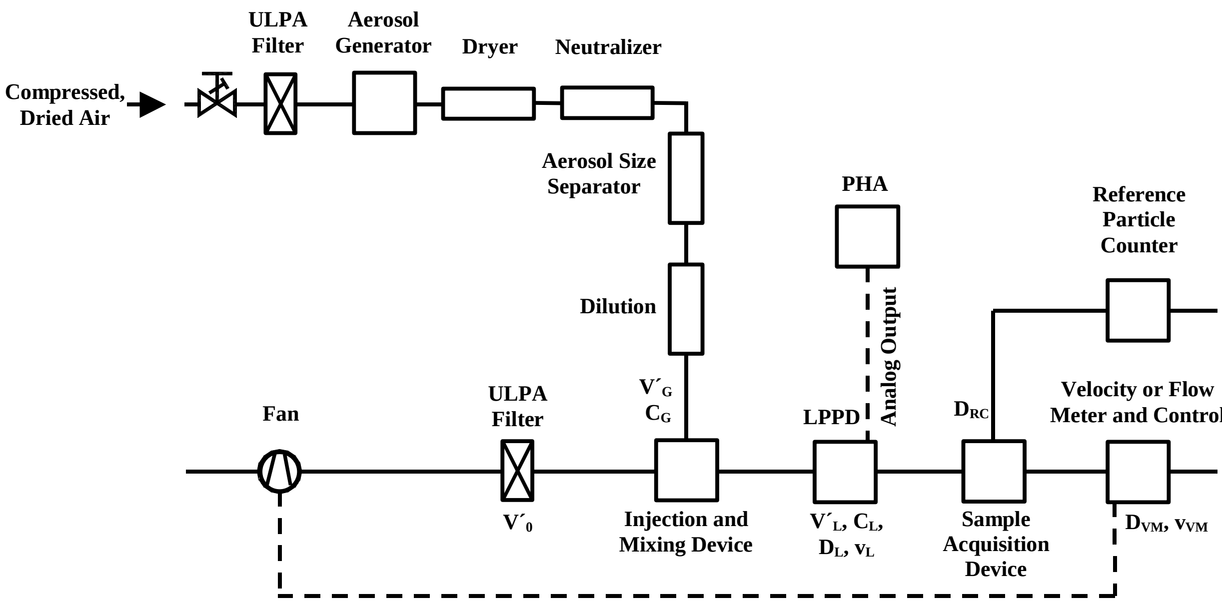


**Figure 1**
**Calibration setup and schematic**

9.3 *Calibration Procedure*

NOTE 10: Specific procedures for calibrating different LPPDs can vary considerably not only between manufacturers but between instrument models. For this reason, this document cannot provide detailed procedures for calibrating every LPPD. For detailed procedures for calibrating a specific LPPD, contact the manufacturer. The calibration should be performed by a skilled technician.

9.3.1 If the aerosol flow rate is varied, then particle residence time in the detection area $A_L$ will also vary. This results in pulses of varying duration. Therefore, the particle velocity $v_L$ at the LPPD should be constant and independent of the line diameter $D_L$. The fan has to be regulated so that the aerosol velocity at the velocity meter is $v_{VM} = v_L\ D^2_L\ /\ D^2_{VM}$. At a constant volume flow rate $V'_G$ (depending on the pressure of the compressed air) and constant number concentration $C_G$ the level of number concentration $C_L$ reaches a value dependent on line diameter $D_L$ at constant velocity $v_L$. With the known detection area $A_L$ of the LPPD, the number of particles per time (counts per $mm^2$ detection area per time) is defined. The RPC monitors the number of particles $C_L$ of the aerosol generator and the zero air inside the line.

9.3.2 If the response signal for the used particle size does not meet the expectations, the operator might use another particle size within the required size range.

9.3.3 *Calibration Parameters*

9.3.3.1 The sample measurement time for the calibration with each particle size should be at least 30 seconds to avoid statistical errors.

9.3.3.2 The calibration is to be performed at ambient atmospheric pressure in a controlled environment (temperature, humidity, vibrations).

9.3.3.3 The calibration of the LPPD is to be executed in a line diameter $D_L$ in which the LPPD should be installed by the user.

9.3.3.4 Fixed particle concentration at the LPPD $C_P$ to ensure that the coincidence error is always less than 10%.

9.3.3.5 Fixed velocity at the LPPD: $v_L = 1$ m/s (independent of line diameter at the LPPD).

9.3.3.5.1 Some LPPDs, e.g. a scanning LPPD for the use inside a process chamber, require a different velocity than 1 m/s for calibration. In such cases the used aerosol velocity at the location of the LPPD shall be reported in the calibration report form.

9.3.4 *Initial Setup*

9.3.4.1 Connect the aerosol generator to a supply of filtered, dried, and compressed zero gas (see Figure 1). Connect a dryer, neutralizer, and size separator (if necessary) to the aerosol outlet of the particle generator. If a dilution of the aerosol before the injection in the calibration line is necessary, install a dilution stage behind the size separator.

9.3.4.2 Connect the aerosol line to the calibration line. Mount the LPPD under test behind the injection and mixing device. Install the sample acquisition device and the velocity or flow meter into the calibration line.

9.3.4.3 Connect a PHA to the sensor calibration output if an appropriate built-in PHA is not available.

9.3.4.4 Before starting the following procedures, make sure all instruments are turned on and allow a certain time for warm-up and temperature stabilization.

9.3.4.5 Purge the aerosol line and the calibration line with filtered and dried air for a minimum of 30 minutes.

9.3.4.6 Check the quality of the zero gas and the condition of the calibration line using the RPC. Collect counts for three one-minute periods and determine the average number of particles reported in counts per minute. The volume flow of the zero gas shall be enough for correct operation of the RPC. Record the cumulative particle count reported for the zero gas for particles equal to and larger than the LDL of the LPPD under test.

9.3.4.7 Clean the aerosol generator liquid reservoir and fill it with clean diluent (particle-free deionized or destilled water or Isopropanol). Run the aerosol generator and adjust the pressure and flow rates as recommended by the aerosol generator manufacturer. Check the condition of the aerosol line using the RPC. Collect counts for three one-minute periods and determine the average number of particles reported per liter of air. If the number exceeds 1 particle per liter air, the diluent shall be refiltered before further use. The average number of particles (counts per minute) should be reported in the calibration report form.

9.3.4.8 Adjust the volume flow through the calibration line for the stipulated aerosol velocity at the LPPD under test.

9.3.4.9 Allow a certain time for stabilization of the adjusted calibration parameters before any test is performed.

9.3.5 *Sizing LPPD*

NOTE 11: For more information and background see Appendix 2.

9.3.5.1 *Size Calibration*

NOTE 12: To define the calibration settings either the mode or median of the voltage pulse distribution could be used. The use of the modal procedure is common. The calibration report form should identify the used method.

9.3.5.1.1 By running different monodisperse aerosols (with $v_L$ and $V'_L = V'_0 + V'_G$), size calibration is performed. Begin with the largest particles for which a calibration value is required. Select the particle size range for which calibration is required. Be sure that the particle concentration is low enough that predominantly individual pulses are generated by the LPPD. Accumulate enough data to avoid statistical errors. The procedure is repeated for each particle size of interest. Determine the average LPPD pulse voltage amplitude with the PHA.

9.3.5.1.2 The mode of the voltage pulse distribution is determined by the highest point in the distribution. If the distribution is interfered with noise near the peak and the peak is not well defined, the data should be averaged and the peak of the averaged distribution should be used defining the mode.

9.3.5.1.3 The median voltage is determined by defining a “Region of Interest” (ROI) which includes the peak representing the voltage pulses from single polymer spheres. The PHA determines the total number of pulses under this peak. The median voltage is that voltage which devises the number of pulses in the region such that half are greater and half are less than the median.

NOTE 13: If the procedure is carried out for the smallest size of which the LPPD is specified, record the noise level of the LPPD. The average voltage for this size should be at least 10% higher than stated noise level voltage at which one noise pulse occurs in one minute.

9.3.5.1.4 The particle size and the average voltage should be reported in the calibration report form.

9.3.5.1.5 For calibration checks, a reference particle counter (RPC) with a good sizing capability could be used. The counting efficiency of the RPC is defined as 100% for the particle sizes used in test. The counts of the RPC and the LPPD under test in the corresponding channel should be normalized to a standard detection area ($mm^2$). The ratio of these counts (in %), the employed particle size and the threshold settings should be recorded in the calibration report form.

9.3.5.2 *Zero Counting*

NOTE 14: The intent of this procedure is not to adjust the thresholds for the zero count rate but to verify whether the LPPD is within its specification.

9.3.5.2.1 By running zero gas (with $v_L$ and $V'_L = V'_0$) through the system the zero count rate, specified by the sensor manufacturer, is checked. The reference particle counter is used to check the quality of the zero gas. The minimum acceptable sample time is 10 minutes. The sampling time shall be long enough to provide adequate sampling statistics. The zero count rate (average counts per minute) should be recorded in the calibration report form.

9.3.5.3 *Counting Efficiency*

NOTE 15: The actual particle concentration is determined with a reference particle counter with a 100% counting efficiency for the employed particle size. It is important that there are no differences between the concentration within the detection area of the LPPD and the concentration monitored by the RPC.

9.3.5.3.1 By running a monodisperse aerosol (with $v_L$ and $V'_L = V'_0 + V'_G$), the maximum of detected particles is counted. The ratio of the counts of the LPPD standardized per $mm^2$ to the counts of the reference particle counter per $mm^2$ detection area (in %) for each particle size should be recorded in the calibration report form.

9.3.5.4 *Sensitivity*

9.3.5.4.1 By running different monodisperse aerosols (with $v_L$ and $V'_L = V'_0 + V'_G$) with particle sizes at the expected sensitivity where the counting efficiency is between 40% and 60%, the sensitivity is verified. The counts of the LPPD per $mm^2$ detection area compared to the counts of the reference particle counter per $mm^2$ detection area (in %) should be determined. The determined particle size shall have a counting efficiency between 40% and 60% and should be recorded in the calibration report form.

9.3.5.5 *Particle Size Resolution*

NOTE 16: The particle size shall be at least twice the lower counting limit to ensure measurement of the entire distribution and accurate characterization of the calibration response curve below the particle size of interest. The resolution is specified by the coefficient of variation (in %) obtained by dividing the portion of the standard deviation of the distribution $\sigma_{LPPD}$ that is contributed by the LPPD by the mean size of the distribution $d_p$.

9.3.5.5.1 Record the size $d_p$ and the standard deviation $\sigma_{d,p}$ of the used particles in the calibration report form. By running a monodisperse aerosol (with $v_L$ and $V'_L = V'_0 + V'_G$), determine the standard deviation of the observed particle distribution $\sigma_{p,LPPD}$. To determine the standard deviation of the pure sensor signal $\sigma_{V,LPPD}$, a pulse height analyzer can measure the voltage peaks at the analog sensor calibration output. The portion of the standard deviation of the distribution $\sigma_{LPPD}$ that is contributed by the LPPD is calculated by the following formula:

$$\sigma_{LPPD} = \sqrt{\left(\sigma_{p,LPPD}\right)^2 - \left(\sigma_{d,p}\right)^2}$$

9.3.5.5.2 The value of the standard deviation of the observed distribution $\sigma_{p,LPPD}$, the standard deviation of the sensor signal $\sigma_{V,LPPD}$, and the coefficient of variation (in %) should be recorded in the calibration report form.

9.3.6 *Non-Sizing LPPD*

NOTE 17: For more information and background see Appendix 2.

9.3.6.1 *Zero Counting*

9.3.6.1.1 See Section 9.3.5.2.

9.3.6.2 *Counting Efficiency*

NOTE 18: The actual particle concentration is determined with a reference particle counter with a 100% counting efficiency for the employed particle size. It is important that there are no differences between the concentration within the detection area of the LPPD and the concentration monitored by the RPC.

9.3.6.2.1 By running a monodisperse aerosol (using the smallest particles size which can be counted with $v_L$ and $V'_L = V'_0 + V'_G$), the maximum of detected particles is counted. The counts of the LPPD per $mm^2$ detection area compared to the counts of the reference particle counter per $mm^2$ detection area (in %) and the employed particle size should be recorded in the calibration report form. These measurements should be executed for the defined set of particle sizes including one size no larger than 1.3 times the sensitivity limit as specified by the manufacturer.

9.3.7 *Interim Procedure*

9.3.7.1 Between the settings of the separate thresholds or the runs with different particle sizes, the system should be purged with zero gas for a sufficient time. The aerosol generator should be rinsed with clean diluent for a sufficient time before adding new suspension of particles with other size.

## 10 Calibration Report Form

10.1 The calibration report form shall contain the following information:

10.1.1 General part:

- Date and time of calibration
- Name of the operator
- Manufacturer of the LPPD
- Model and serial number of the LPPD to be calibrated (if sensor and counter are separate, model and serial number for each)
- Size of the detection area (if detection area is dependent on the particle size, all established values)
- Model, serial number, manufacturer, and date of last calibration of the reference particle counter
- Performance of the reference particle counter (volume flow, sensitivity, zero count rate)
- Environmental conditions: temperature $T_A$, relative humidity RH, pressure p
- Quality of zero gas as measured with the reference particle counter (counts per minute)
- Specifications of the particles used for calibration (manufacturer, certified size and tolerance, standard deviation $\sigma_{d,p}$, coefficient of variation, refractive index, lot number)
- Calibration parameters: particle concentration $C_L$, particle velocity $v_L$ at the location of the LPPD, line diameter $D_{L,}$ opening area $A_{RC}$ of the probe inlet for each particle size
- Calibration procedure: sizing or non-sizing

10.1.2 For sizing LPPD:

- Size calibration: value of the average voltage of the different particle sizes, employed particle sizes, mode or median method
- Size calibration check: values of the thresholds, employed particle sizes, ratio of the normalized counts in the corresponding channel (in %)
- Zero counting: value of the zero count rate (average counts per minute), sampling time
- Particle size resolution: value of coefficient of variation, value of standard deviation of the observed distribution, mean size of the distribution, value of standard deviation of the sensor signal, employed particle sizes
- Counting efficiency: value of the counting efficiency (in %), employed particle sizes

10.1.3 For non-sizing LPPD:

- Zero counting: value of the zero count rate (average counts per minute), sampling time
- Counting efficiency: value of the counting efficiency (in %), employed particle sizes

10.2 Report significant variations from data reported from the previous calibration.

## 11 Related Documents

NOTE 19: These publications related to particle measurement, vacuum ISPM, and calibration are just informative to improve understanding of these standard.

Raasch, J.; Umhauer, H.: “Errors in Determination of Particle Size Distributions Caused by Coincidence in Optical Particle Counters” Particle Characterization 3, 1990, 424-427

Jaenicke, R.: “The Optical Particle Counter: Cross Sensitivity and Coincidence” J. Aerosol Sci., 30(5), 1972, 95-111

Borden, P.: “Monitoring Vacuum Process Equipment: In Situ Monitors – Design and Specification” Microcontamination, 1991, 43-47

Raabe, O.G.: “The Generation of Aerosols of Fine Particles” Fine Particles, Ed. Liu, B.; Academic Press, New York, 1976, 57-110

# APPENDIX 1
# PERFORMANCE TESTING

**NOTICE**: The material in this appendix is an official part of SEMI E104 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

A1-1 The definitions of parameters and measurement of the terms described in SEMI E10 applies also to LPPDs and combined LPPD/process equipment.

# APPENDIX 2
# CALIBRATION NOTES

**NOTICE**: The material in this appendix is an official part of SEMI E104 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

## A2-1 Size Calibration

A2-1.1 Size calibration is performed with monodisperse particles with known sizes and known optical properties. The procedure establishes the voltage response of the LPPD for these particles. The reported size for unknown particles is the same size of the monodisperse particle whose voltage response is the voltage pulse produced by the unknown particle (called Optical Equivalent Size).

A2-1.2 If an LPPD is able to detect all of the distribution (see counting efficiency) generated by a monodisperse aerosol and the size of the particle standard is known, the calibrating of an LPPD without a reference particle counter is possible. Ideally, the data collected by the LPPD observing a monodisperse aerosol would describe a Gaussian particle size distribution. However, the reported voltage pulse height distribution is often not symmetric. Therefore, the mode and modal values of the pulse height distribution are not equal. The thresholds for different particle sizes are set as the mode or median value of the observed distribution. The modal voltage method is commonly used.

A2-1.3 The intensity of the scattered light detected by a photodetector depends on intensity, polarization state, and wavelength of the incident light beam, diameter, shape, and refractive index of the particle, as well as on the geometrical layout of the collection optics and detector. In the particle size range near the wavelength ($0.1\lambda < d_P < 10\lambda$), large oscillations can be seen in the intensity curve of the light scattered by spherical particles as a function of all these parameters. Therefore, the response curve might not be monotonic. Particles of more than one size will produce the same voltage output signal. The calibration particles should be chosen so that their response is not included in such reversals of the calibration curves.

A2-1.4 For calibration checks, a reference particle counter (RPC) with a good sizing capability could be used. The counting efficiency of the RPC shall be 100% for the particle sizes used in test. The counts of the RPC and the LPPD under test in the corresponding channel should be normalized to a standard detection area ($mm^2$).

## A2-2 Particle Size Resolution

A2-2.1 Particle size resolution of a particle detector describes its capability to differentiate between particles of nearly the same size, or it is a measure of the range of sizes which the counter would assign to a particular particle if its size was determined repeatedly. The resolution is specified by the coefficient of variation (in %) obtained by dividing the portion of the standard deviation of the distribution $\sigma_{LPPD}$ that is contributed by the LPPD by the mean particle size.

A2-2.2 The employed particle size should be at least 2 times larger than the lower detection limit of the instrument and is within a monotonic response range of the LPPD response curve. The size $d_p$ and the standard deviation $\sigma_{d,p}$ of the used particles is necessary to calculate the resolution.

A2-2.3 To determine the resolution, the standard deviation of the observed particle distribution $\sigma_{p,LPPD}$ is calculated. The quality of the photodetector is checked by determining the standard deviation of the pure sensor signal $\sigma_{V,LPPD}$ at the analog calibration output with a pulse height analyzer. The $\sigma_{LPPD}$ is calculated by the following formula:

$$\sigma_{LPPD} = \sqrt{\left(\sigma_{p,LPPD}\right)^2 - \left(\sigma_{d,p}\right)^2}$$

## A2-3 Zero Counting

A2-3.1 The intent of this procedure is not to adjust the thresholds for the zero count rate but to verify whether the LPPD is within its specification. It is assumed that the zero count level of a correct operating LPPD is sufficiently better than its specification. Failure of the verification test is due to a physical failure within the LPPD and not to statistical variation in the measurement.

A2-3.2 The output of a photodetector and the electronic circuits of the particle detector is afflicted with noise. The zero count rate verification is carried out to ensure that data, especially near the detection limit of the LPPD, is generated by particles rather than by noise. To achieve this goal, the basic thresholds for the LDL are to be set so that a signal-to-noise ratio of at least 3 dB is ensured. The sampling time shall be long enough to provide adequate sampling statistics.

## A2-4 Counting Efficiency

A2-4.1 The counting efficiency for a specific particle size is defined as the ratio of the detected concentration of particles to the concentration actually present. The determination of the counting efficiency of an LPPD requires particles of known size and concentration in the aerosol. The counting efficiency is affected by several factors.

- First, the counting efficiency is dependent on a specific particle size.
- The effect of particle concentration is addressed under zero counting and coincidence.
- Due to inhomogeneous light intensity within the detection area of the particle counter, not all small particles near the lower detection limit of the instrument are detected.
- If the sampling flow is not completely contained within the defined detection area, then some portions of the aerosol will not be counted.

A2-4.2 Ideally, the counting efficiency of a particle counter covering 100% of the line cross-section area as detection area would consist of a step function at the point of the LDL. Real particle detectors have a gradual transition (efficiency curve) instead of a step function. The point with 50% detection probability of all particles of a given size moving through the detection area is often used as a reference point. The corresponding particle size is called the minimum detectable particle size (see sensitivity). If the slope of the efficiency curve for two detectors with the same specified 50% efficiency point is different, the two detectors may show different particle counts for the same polydisperse aerosol. To define an efficiency curve, more than one particle size, e.g. 5 particle sizes around the LDL covering 0% to 100% efficiency, should be used. Acceptable counting efficiency for single particle counting instruments is 50% ± 20% at the minimum detection size and 100% ± 10% for all particles larger than 1.5 times the minimum size.

A2-4.3 The detection area of most LPPDs comprises only a small portions of the cross-section area of the line. Therefore, it is not possible to specify a 50% efficiency point. For this, the commonly used definition for sensitivity could not be used for such instruments.

A2-4.4 The actual particle concentration is determined with a reference particle counter with a 100% counting efficiency for the employed particle size. It is important that there are no differences between the concentration within the detection area of the LPPD and the concentration monitored by the RPC.

## A2-5 Sensitivity

A2-5.1 The particle size corresponding to the point with 50% counting efficiency of the particles of a given size is defined as the minimum detectable particle size. This is valid only for particle counters capable to reach 100% counting efficiency for a specific particle size. This does not apply to most LPPDs.

## A2-6 Particle Concentration Effects

A2-6.1 All optical particle detectors are able to operate accurately only within a limited range of particle concentration. It is not the scope of this document to define how this limit is measured or how to verify the specification.

A2-6.2 *High Concentration Effects*

A2-6.2.1 The upper limitation of the particle concentration is chiefly based on coincidence effects.

A2-6.2.2 One effect is optical coincidence. If the particle concentration is too high, more than one particle is present within the detection area of the instrument. The reported particle concentration will be less than the true value, and the reported particle size distribution will be shifted towards the indication of larger particles than in reality.

A2-6.2.3 The other effect is electronic coincidence. It is defined as the inability of the electronic pulse processing system to detect and size individual pulses that are too closely spaced. If there are so many pulses that they cannot completely return to the baseline, they become superimposed. Electronic saturation occurs. Electronic coincidence introduces errors in both particle size and counts as well. Normally, this problem is not critical for modern electronic systems. Optical coincidence can become a problem at particle levels well below the point where electronic saturation occurs.

A2-6.2.4 Another error can occur when high concentrations of particles just smaller than the lower detection limit of the instrument are present. Even though no single one of these particles will be detected, scattering-light levels from these particles can increase the background optical noise level. So, errors might be produced in particle count data in the lower particle size ranges reported by the counter.

A2-6.3 *Low Concentration Effects*

A2-6.3.1 It is obvious that it is necessary to collect sufficient data to determine number and size of particles within an acceptable confidence limit.

# APPENDIX 3
# AEROSOL GENERATION AND AEROSOL DILUTION

**NOTICE**: The material in this appendix is an official part of SEMI E104 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

## A3-1 Monodisperse Particle Suspension

A3-1.1 Monodisperse suspensions of particles (PSL) are available in sizes from 0.02 μm. These particles are grown by emulsion polymerization and are stabilized in aqueous suspensions with an anionic surfactant. They carry a negative charge which contributes to their stability. The suspension normally contains 10% solids and 2% dissolved, highly viscous stabilizer. The solid contains up to 8% emulsifier and inorganics.

A3-1.2 After evaporation, these solids and the stabilizer will both increase the diameter of the single particle and generate a residual nucleus out of an empty droplet. These residual particles are called secondary aerosol. The diameter of residual nucleus could be up to 0.25 μm according to the PSL size and dilution of the suspension. Most of these secondary aerosol particles might be too small to be detectable with commonly used particle detectors, but they will have an influence on the noise level because of there high number.

A3-1.3 Out of a high-concentration suspension it is not possible to aerosolize only individual particles. Droplets containing more than one of the suspended particles will become undesirable agglomerates upon evaporation.

A3-1.4 For this, an adequate dilution of the suspension is necessary to avoid the formation of aggregates and the enlargement of the particles.

## A3-2 Generation and Dilution of PSL Suspension

A3-2.1 A diluted PSL suspension for particle generation in an aerosol generator can be created by the following procedure:

- Shaking and/or ultrasonic treatment of the PSL bottle distributed by the PSL manufacturer.
- Placing one drop of PSL in one liter of deionized or destilled water or Isopropanol. The water could be cleaned using a filter with a pore size no more than 10% of the size of the particles being used.
- Shaking and/or ultrasonic treatment of the suspension to disperse the particles.

A3-2.2 The suspension will probably need to be diluted further to provide a required particle concentration. This is necessary to avoid the formation of agglomerates and to restrict the size of the secondary aerosol particles. An equation to calculate the required particle concentration is given in “The Generation of Aerosols of Fine Particles” by O. Raabe (see Section 11).

A3-2.3 The particle suspensions distributed by the PSL manufacturer shows no detectable variation in particle characteristics when they are stored in a cool place over the years. Diluted suspensions for atomization feature an aging process. Diluted suspensions of polymer spheres smaller than 1 μm should not be stored for more than one week.

NOTE A3-1: Care should be taken to avoid contamination of the polymer spheres and the suspension.

## A3-3 Aerosol Generation

A3-3.1 The diluted suspension is nebulized in the aerosol generator. Great account is taken of concentration and size distribution of the generated droplets and of the volume flow rate $V'_G$. To achieve a constant aerosol production, the volume flow rate and the droplet size distribution should be constant and independent of the supplies of suspension in the reservoir. The variation in particle concentration should be no more than 10% as measured by the reference particle counter over a time period of 15 minutes or more.

NOTE A3-2: Care should be taken to avoid contamination of the aerosol generator.

## A3-4 Aerosol Drying

A3-4.1 The water of the generated droplets will completely evaporate when the relative humidity of the aerosol flow behind the nebulizer is lower than 70%. The volume flow of the suspension in the nozzle increases the humidity of the filtered compressed air which has a relative humidity of 10%–15% in spite of predrying. The use of a diffusion dryer or another appropriate instrument allows a higher relative humidity of the aerosol flow behind the aerosol generator. The diffusion dryer uses silica gel desiccant to remove the moisture. The desiccant shall either be new or freshly regenerated. It is not wise to get the aerosol in direct contact with the desiccant. Polymer spheres will be precipitated and additional particles out of the desiccant will change the particle size distribution of the aerosol.

### A3-5 Aerosol Neutralization

A3-5.1 When dispersing the suspension, the particles are charged. This surface charge should be removed after drying the aerosol flow to avoid electrostatic interactions with each other or the line walls. With the help of the discharging distance of an electrostatic neutralizer, the aerosol is exposed to a bipolar ion source. Some electrostatic neutralizers may produce a large number of ultra-fine particles which will combine with the calibration aerosol and affects the signal-to-noise-ratio of the LPPD and the reference particle counter.

### A3-6 Aerosol Size Separation

A3-6.1 When calibrating with ultra-fine particles, a particle size separation might be necessary to remove the residue particles and agglomerates. An electrostatic classifier is most effective for particle sizes less than 1 µm. This instrument electrically charges the incoming aerosol. With electrostatic deflection, it separates selected particles of one mobility. The residue particles and the larger aggregate particles would be stripped out of the particle stream consisting of the desired polymer particles. To charge the aerosol, the electrostatic classifier uses a radioactive neutralizer. The aerosol exiting the instrument will contain singly charged particles. This low charge level makes the use of an additional aerosol neutralizer unnecessary. Nevertheless, conductive tubing should be used between the aerosol generator and the LPPD and reference particle counter to minimize electrostatic particle loss.

### A3-7 Aerosol Dilution

A3-7.1 The particle concentration of the aerosol generated by the nebulizer might be too high. The aerosol should be further diluted to achieve the required concentration and to avoid coincidence errors. The dilution could be executed with a mixing chamber in which the aerosol is mixed with zero gas. The internal chamber pressure should be stable and very close to ambient atmospheric pressure at operational flow rates. The spatial particle distribution in the exiting aerosol should be as homogenous as possible.

# APPENDIX 4
# AEROSOL TRANSPORT AND AEROSOL SAMPLING

**NOTICE**: The material in this appendix is an official part of SEMI E104 and was approved by full letter ballot procedures on July 28, 2000 by the European Regional Standards Committee.

## A4-1 Aerosol Transport

A4-1.1 Aerosol loss in lines occurs both for small and larger particles. Larger particles (approximately 5 μm and larger) are lost as a result of gravitational settling in horizontal lines and inertial effects in all lines. Smaller particles are lost to the line walls by diffusion and by electrostatic charge effects.

A4-1.2 A limitation of particle loss could be achieved with tubing as short and as straight as possible with no bends with a radius of curvature less than 100 mm. The tubing of the calibration setup should be smooth, conductive, and electrically grounded. Stainless, polished steel for rigid lines and Polyurethane or polyvinyl chloride for flexible lines is found acceptable for handling most aerosols with low electrostatic particle loss. If long transit lines are required, they should be sized to permit a Reynolds number in the range of 5,000 to 25,000 at the sample flow rate to minimize particle residence time in the tubing without causing excessive turbulence at high flow rates.

## A4-2 Aerosol Sample Acquisition

A4-2.1 The term isokinetic sampling often is used in aerosol measurement and characterization. Isokinetic sampling of particles in a moving aerosol is performed by matching the sample probe inlet velocity (flow speed <u>and</u> direction) to the velocity of the moving aerosol. At velocities less than 15 m/s, anisokinetic sampling errors are negligible for most particles smaller than approximately 5 μm. Losses of larger particles might be significant. The larger the particle, the larger the loss due to inertial effects. Isokinetic sampling is not possible in environmental conditions with varying velocity, motionless air, and turbulent, random, or non-unidirectional flow. For better sampling inlet efficiency, isokinetic or at least isoaxial sampling is recommended at calibration.

# SEMI E106-1104

# OVERVIEW GUIDE TO SEMI STANDARDS FOR PHYSICAL INTERFACES AND CARRIERS FOR 300 mm WAFERS

This guide 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 July 11, 2004 and August 16, 2004. Initially available at www.semi.org September 2004; to be published November 2004. Originally published October 2000; previously published March 2003. This document replaces SEMI PR6-0200 in its entirety.

## 1 Purpose

1.1 This document is intended to help users and suppliers of 300 mm carriers and production equipment to understand the complex interdependencies among the SEMI standards for 300 mm physical interfaces and carriers and to determine which standards apply to which products. As shown in Figure 1, these standards are highly inter-related, have many complex dependencies, and inherit a numbering system (from legacy 200 mm standards) that is non-intuitive.

## 2 Scope

2.1 This document describes how the SEMI standards for 300 mm physical interfaces and carriers work together. This document also clarifies the requirements (direct and indirect) on suppliers of each product, and suggests how users see these standards and options.

**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.

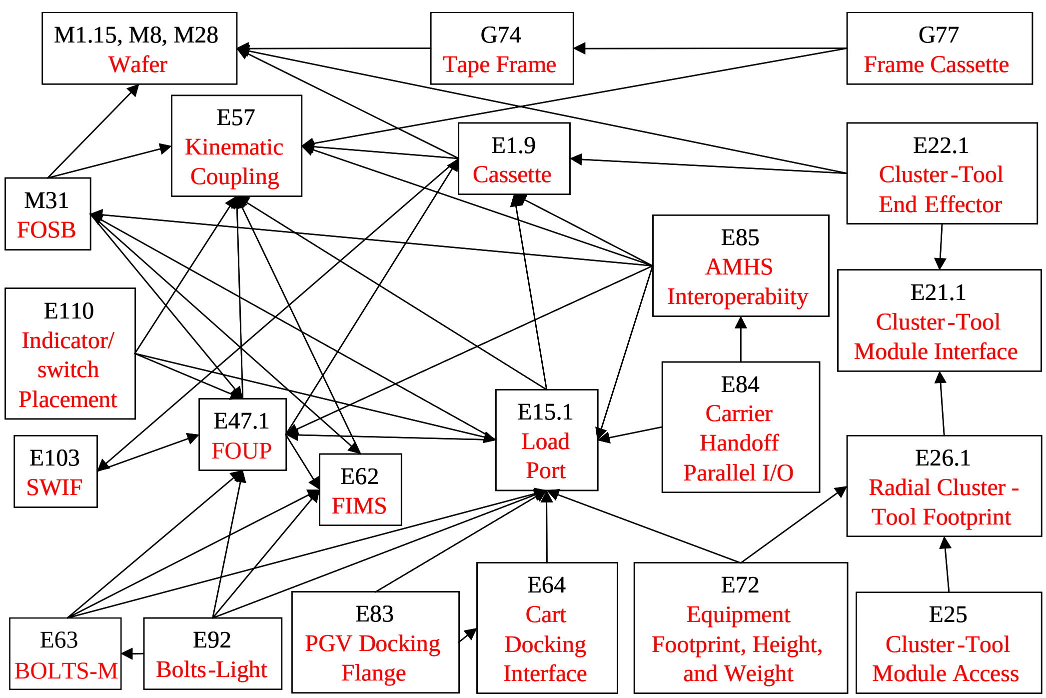


**Figure 1**
**Complex Relationships and Dependencies Among 300 mm Standards**

## 3 Limitations

3.1 *300 mm Only* — This document only covers SEMI standards that are specific to 300 mm, even though other standards may apply to 300 mm equipment. For example, standards not described here include:

- metrics documents such as SEMI E10;
- minienvironment documents such as SEMI E45 and and SEMI E46;
- facilities documents such as SEMI E70;
- reticle handling documents such as SEMI E100 which specifies a reticle SMIF pod for 6-inch or 230 mm reticles based on SEMI E19.4; or
- safety documents such as SEMI S2, SEMI S8, SEMI S11 and an upcoming Safety Guideline for Unmanned Transport Vehicle (UTV) Systems.

3.2 *Physical Interfaces and Carriers Only* — This document also does not cover standards that were generated by committees other than the SEMI Physical Interfaces and Carriers Committee, even though such standards may be specific to 300 mm. For example, standards not described here include:

- Information and Control documents such as SEMI E82; and
- Silicon documents such as SEMI M1.15, SEMI M8, and SEMI M28 (Developmental Wafers).

## 4 Referenced Standards

4.1 *SEMI Standards*

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

SEMI E10 — Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM)

SEMI E15 — Specification for Tool Load Port

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

SEMI E19 — Standard Mechanical Interface (SMIF)

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

SEMI E21.1 — Cluster Tool Module Interface 300 mm: Mechanical Interface and Wafer Transport Standard

SEMI E22.1 — Cluster Tool Module Interface 300 mm: Transport Module End Effector Exclusion Volume Standard

SEMI E23 — Specification for Cassette Transfer Parallel I/O Interface

SEMI E25 — Cluster Tool Module Interface: Module Access Guideline

SEMI E26.1 — Radial Cluster Tool Footprint 300 mm Standard

SEMI E45 — 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)

SEMI E46 — Test Method for the Determination of Organic Contamination from Minienvironments Using Ion Mobility Spectrometry (IMS)

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

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 E63 — Mechanical Specification for 300 mm Box Opener/Loader to Tool Standard (BOLTS-M) Interface

SEMI E64 — Specification for 300 mm Cart to SEMI E15.1 Docking Interface Port

SEMI E70 — Guide for Tool Accommodation Process

SEMI E72 — Specification and Guide for 300 mm Equipment Footprint, Height, and Weight

SEMI E82 — Specification for Interbay/Intrabay AMHS SEM (IBSEM)

SEMI E83 — Specification for 300 mm PGV Mechanical Docking Flange

SEMI E84 — Specification for Enhanced Carrier Handoff Parallel I/O Interface

SEMI E85 — Specification for Physical AMHS Stocker to Interbay Transport System Interoperability

SEMI E92 — Specification for 300 mm Light Weight and Compact Box Opener/Loader to Tool-Interoperability Standard (BOLTS/Light))

SEMI E99 — The Carrier ID Reader/Writer Functional Standard: Specification of Concepts, Behavior, and Services

SEMI E99.1 — Specification for SECS-I and SECS-II Protocol for Carrier ID Reader/Writer Functional Standard

SEMI E100 — Specification for a Reticle SMIF Pod (RSP) Used to Transport and Store 6 Inch or 230 mm Reticles

SEMI E101 — Guide for EFEM Functional Structure Model

SEMI E103 — Provisional Mechanical Specification for a 300 mm Single-Wafer Box System that Emulates a FOUP

SEMI G74 — Specification for Tape Frame for 300 mm Wafers

SEMI G77 — Specification for Frame Cassette for 300 mm Wafers

SEMI M1.15 — Standard for 300 mm Polished Monocrystalline Silicon Wafers (Notched)

SEMI M8 — Specification for Polished Monocrystalline Silicon Test Wafers

SEMI M28 — Specifications for Developmental 300 mm Diameter Polished Single Crystal Silicon Wafers

SEMI M29 — Specification for 300 mm Shipping Box

SEMI M31 — Provisional Mechanical Specification for Front-Opening Shipping Box Used to Transport and Ship 300 mm Wafers

SEMI S2 — Environmental, Health, and Safety Guideline for Semiconductor Manufacturing Equipment

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

SEMI S11 — Environmental, Safety, and Health Guidelines for Semiconductor Manufacturing Equipment Minienvironments

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

## 5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *AGV* — automatic guided vehicle (as defined in SEMI E101).

5.1.2 *PGV* — person guided vehicle (cart) (as defined in SEMI E101).

5.1.3 *RGV* — rail guided vehicle (moving on the floor) (as defined in SEMI E101).

5.2 *Definitions*

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

5.2.2 *BOLTS plane* — a plane parallel to the facial datum plane near the front of the tool where the box opener/loader is attached (as defined in SEMI E63).

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

5.2.4 *box opener/loader* or *BOLTS unit* — the equipment component that opens wafer carriers (if needed) and presents the carriers to the equipment's wafer handler for unloading and loading wafers (as defined in SEMI E63).

5.2.5 *carrier handler* — receives and passes the carriers from and/or to the external system (such as the factory material handling system). A carrier handler of the internal buffer type has the functions of handling and storing the carriers. A carrier handler for FOUPs has the opener(s) for opening and closing FOUPs.

5.2.6 *cart* — a floor-based carrier transfer vehicle (as defined in SEMI E101).

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

5.2.8 *docking* — the act of locating a floor-based carrier transport vehicle for carrier transfer to/from equipment (as defined in SEMI E101).

5.2.9 *equipment front end module (EFEM)* — consists of the carrier handler that receives carriers from the factory material handling system on one or more load ports (as specified in SEMI E15.1), opens the carriers (if needed), and may include a substrate handler for unloading and loading wafers from the carrier to the process part of the equipment (as defined in SEMI E101).

5.2.10 *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).

5.2.11 *fixed buffer* – EFEM configuration with carrier places only on load port units arranged in a load port group (as defined in SEMI E101).

5.2.12 *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) (as defined in SEMI E47.1).

5.2.13 *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).

5.2.14 *internal buffer* — EFEM configuration with carrier places different from load port units (as defined in SEMI E101).

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

5.2.16 *OHT* — overhead transport system with hoist for lifting carriers between load port level and transport level (as defined in SEMI E101).

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

5.2.18 *substrate handler* — transfers substrates between carriers and the process part of the equipment (as defined in SEMI E101).

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

## 6 Description of the Standards

6.1 *Overview* — Figure 2 shows roughly what most of the SEMI standards for 300 mm physical interfaces and carriers specify. However, this picture is greatly over-simplified. For example, a front-opening shipping box (FOSB) compliant with SEMI M31 (with its thicker door) generally cannot be opened by equipment load ports that are compliant with SEMI E63. Also, a wire link to an OHT for the carrier handoff parallel I/O can also be located at the top of the equipment. Furthermore, the atmospheric wafer handler for emptying the carrier will generally be different from the wafer handler used in the vacuum environment of the central handler module of a cluster tool.

6.2 *Kinematic Coupling* — The foundational document of the SEMI standards for 300 mm physical interfaces and carriers is SEMI E57 which specifies the mechanical couplings used to ergonomically align and precisely support 300 mm wafer carriers. The kinematic coupling consists of three pins that mate with grooves on the bottom of the wafer carrier (which are not specified) for physical alignment and support. Most of the dimensions in the SEMI standards for 300 mm physical interfaces and carriers are determined with respect to the three orthogonal datum planes defined in SEMI E57: the horizontal datum plane, the facial datum plane, and the bilateral datum plane. Such a kinematic coupling can be used at several interfaces, including:

- between a FOUP or cassette and an equipment load port or vehicle nest,
- between a transport cassette and a box, and
- between a process cassette or quartz boat and the floor of a process chamber.

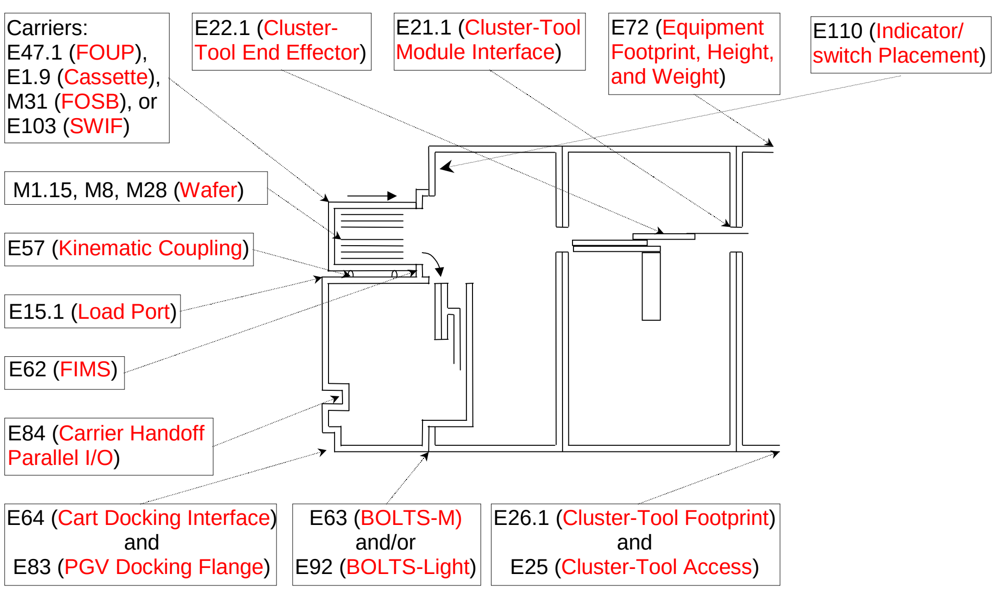


**Figure 2**
**Key Standards for 300 mm Equipment**

6.3 *Wafer Carriers* — SEMI E1.9 and SEMI E47.1 specify the carriers used to transport and store 300 mm wafers in an IC manufacturing facility. SEMI E47.1 specifies the outside features of the front-opening unified pod (FOUP). The inside features of the FOUP are specified in SEMI E1.9, which also specifies the open cassette. Both standards specify carriers that hold either 13 or 25 wafers. SEMI M31 specifies the front-opening shipping box (FOSB) used to transport and ship 300 mm wafers. SEMI E103 specifies a system that includes a box that holds only one wafer and that fits onto an adapter mechanism called a single-wafer interface (SWIF). This system appears to the equipment to be a 300 mm FOUP (except that only the volume around the middle wafer may be accessible).

6.4 *Equipment Load Ports* — SEMI E15.1 specifies the carrier load ports at the front of 300 mm process or metrology equipment (or stockers). In addition, the substrate port that opens a FOUP door is specified in SEMI E62 (FIMS). At the floor below each load port is a cart docking interface exclusion volume specified in SEMI E64; this volume can contain a PGV docking flange as specified in SEMI E83. SEMI E63 (BOLTS-M) or SEMI E92 (BOLTS-Light) or both standards specify the mechanical interface between the main part of a process or metrology tool and the box opener/loader unit that opens FOUPs and presents them to the tool wafer handler for unloading and loading 300 mm wafers. Also associated with each load port is a wire or optical link (from the equipment to the AMHS carrier delivery system) specified in SEMI E84 which is the 300 mm version of SEMI E23. SEMI E99 and SEMI E99.1 specify the electronics and communication interface between a carrier ID reader/writer and the equipment controller. SEMI E101 specifies the functional structure model and component behavior for the entire equipment front-end module (EFEM). SEMI E110 specifies the placement of indicators and switch.

6.5 *Cluster-Tools* — SEMI standards for 300 mm cluster tools include SEMI E22.1, SEMI E21.1, SEMI E26.1, and SEMI E25.

6.6 *AMHS* — SEMI standards for automated material handling systems (AMHS) include SEMI E85.

6.7 *Equipment Volume and Weight* — SEMI E72 specifies limits on the footprint, height, and weight of equipment for 300 mm fabs. Separate limits are given for the parts of the equipment in the main fab and in the sub-fab. Separate limits are also given for the equipment after it is installed and for the components of the equipment as it is moved into the fab.

6.8 *Back-End Standards* — SEMI G74 specifies the tape frames used for 300 mm wafers between the dicing process and the die-bonding process. SEMI G77 specifies the mechanical features of a metal or plastic frame cassette used for framed 300 mm wafers between the wafer mounting process and the die-bonding process. Future standards may also specify the carrier for thinned 300 mm wafers and the load port for back-end process or metrology equipment.

6.9 *Standards of Uncertain Use* — Some SEMI 300 mm standards that passed balloting have a scope of application or extent of use that is yet to be fully determined. Such standards include SEMI M29 which specifies a manually-opening shipping box for 300 mm wafers. In the other SEMI 300 mm standards are also some options of uncertain use such as bottom-opening pods and pods with removable cassettes.

## 7 Application of Standards to Products

7.1 *One-Sided Interface Specifications* — The SEMI standards for 300 mm physical interfaces and carriers are intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter-changeability between different types of products. To accomplish this, only one side of each mechanical interface (between different types of products) is specified, leaving the supplier of the product on the other side of the interface more freedom to improve their product. For example, only the bottom half of the kinematic coupling (the pin) is specified by SEMI E57 so that suppliers can be flexible in designing wafer carrier grooves that can mate with it. Table 1 shows which standards apply to each type of product and shows which side of the interface is specified:

- "D" indicates if the standard directly specifies that type of product (by specifying that product's side of the relevant interface).
- "I" indicates if the standard indirectly specifies that type of product (by specifying the other side of the relevant interface).

7.2 *Carriers* — A FOUP is directly specified by SEMI E47.1 (for its outside features not including the door) and by SEMI E1.9 (for its inside features). The FOUP is indirectly specified by SEMI E57 (for its kinematic coupling grooves) and by SEMI E62 (for its FIMS door interface). Thus, if a FOUP door fails to open or close correctly on any load port that complies with SEMI E57 and SEMI E62, that FOUP is in violation of the standards. The wafer support function of all of the 300 mm carriers is specified directly (by specifying where the wafers must be located rather than specifying the shape and location of the supports), so the 300 mm wafer standards indirectly specify the carriers.

7.3 *Stockers* — A carrier stocker is directly specified by SEMI E57 (for the kinematic coupling pins on its shelves, if any, and on its manual/AGV/RGV and interbay load ports), by SEMI E15.1 (for its manual/AGV/RGV load ports), by SEMI E85 (for its interbay load ports), by SEMI E84 (for its carrier handoff parallel I/O at either kind of load port) and by SEMI E64 (for the cart docking interface exclusion volume below each manual/AGV/RGV load port). The carrier stocker is indirectly specified by the carrier standards (for the volume required to store and transfer the carriers).

7.4 *Carrier ID* — A carrier ID reader/writer unit is directly specified by a future standard that specifies the electronics and communication interface between a carrier ID reader/writer and the equipment controller. The carrier ID reader/writer unit is indirectly specified by the carrier standards (which specify reserved areas for carrier ID tags) and by SEMI E15.1 (for its exclusion volume in each load port).

7.5 *Load Port and Carrier Handler Modules* — A box opener/loader (the module on a piece of equipment that includes load ports and carrier handling) is directly specified by SEMI E57 (for the kinematic coupling pins on the load port and on its shelves if it includes an internal buffer in addition to its fixed buffer), by SEMI E15.1 (for its load ports), by SEMI E62 (for its FIMS door interface), by SEMI E84 (for its carrier handoff parallel I/O), by SEMI E64 (for the cart docking interface exclusion volume below each load port), by SEMI E72 (for its limits on footprint, height, and weight), and by SEMI E110 (for indicator/switch placement). The module is indirectly specified by the carrier standards (for the volume required to store and transfer the carriers) and by SEMI E63 and/or SEMI E92 (for the mechanical interface to the main part of the process or metrology equipment that contains the substrate handler).

7.6 *Main Part of Process or Metrology Equipment* — The main part of process or metrology equipment (including the substrate handler) is directly specified by SEMI E63 and/or SEMI E92 (for the mechanical interface to the module that includes load ports and carrier handling) and by SEMI E72 (for its limits on footprint, height, and weight). The substrate handler is indirectly specified by SEMI E1.9 (for the features inside most carriers) and it is recommended to follow the direct specifications in SEMI E22.1 (which specifies cluster-tool end effectors).

7.7 *Material Handling Systems* — A carrier transport vehicle is directly specified by SEMI E57 (for the kinematic coupling pins on the carrier nest, if any) and by SEMI E84 (for its carrier handoff parallel I/O, if any). The AMHS system is indirectly specified by the carrier standards (for the volume required to hold and transfer the carriers), by SEMI E15.1 (for equipment load ports), by SEMI E85 (for stocker load ports, if it is an OHT), by SEMI E72 (to allow for equipment height, if it is an OHT), and by SEMI E64 and SEMI E83 (for the cart docking interface exclusion volume and the PGV docking flange, respectively, below each equipment load port, if it is a floor based vehicle).

**Table 1  Standards Specifying Each Type of Product (D = Direct Specification, I = Indirect Specification)**

| *Type of Product and its Components* | *SEMI M1.15, M8, or M28 (Wafer)* | *SEMI E57 (Kinematic Coupling)* | *SEMI E1.9 (Cassette)* | *SEMI E47.1 (FOUP)* | *SEMI M31 (FOSB)* | *SEMI E103 (Single-Wafer Box System)* | *SEMI E62 (FIMS)* | *SEMI E63 (BOLTS-M) and/or E92 (BOLTS-Light)* | *SEMI E15.1 (Load Port)* | *SEMI E64 (Cart Docking Interface)* | *SEMI E83 (PGV Docking Flange)* | *SEMI E84 (Carrier Handoff Parallel I/O)* | *SEMI E99 & E99.1 (Carrier ID Reader/Writer Comm.)* | *SEMI E85 (Stocker to Interbay Transport System)* | *SEMI E22.1 (Cluster- Tool End Effector)* | *SEMI E21.1 (Cluster-Tool Module Interface)* | *SEMI E25 & E26.1 (Cluster-Tool Access & Footprint)* | *SEMI E72 (Equipment Footprint, Height, and Weight)* | *SEMI G74 (Tape Frame)* | *SEMI G77 (Frame Cassette)* | *SEMI E110 (Indicator/Switch Placement)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **FOUP:** | | | | | | | | | | | | | | | | | | | | | |
| wafer supports | I | | | | | | | | | | | | | | | | | | | | |
| coupling grooves | | I | | | | | | | | | | | | | | | | | | | |
| inside features | | | D | D | | | | | | | | | | | | | | | | | |
| outside features | | | | D | | | | | | | | | | | | | | | | | |
| door | | | | D | | | I | | | | | | | | | | | | | | |
| **open cassette:** | | | | | | | | | | | | | | | | | | | | | |
| wafer supports | I | | | | | | | | | | | | | | | | | | | | |
| coupling grooves | | I | | | | | | | | | | | | | | | | | | | |
| other features | | | D | | | | | | | | | | | | | | | | | | |
| **shipping box:** | | | | | | | | | | | | | | | | | | | | | |
| wafer supports | I | | | | | | | | | | | | | | | | | | | | |
| coupling grooves | | I | | | | | | | | | | | | | | | | | | | |
| other features | | | | | D | | | | | | | | | | | | | | | | |
| **single-wafer box and SWIF system:** | | | | | | | | | | | | | | | | | | | | | |
| wafer supports | I | | | | | | | | | | | | | | | | | | | | |
| coupling grooves | | I | | | | | | | | | | | | | | | | | | | |
| inside features | | | D | D | | D | | | | | | | | | | | | | | | |
| outside features | | | | D | | D | | | | | | | | | | | | | | | |
| door | | | | D | | D | I | | | | | | | | | | | | | | |
| **interbay transport vehicle:** | | | | | | | | | | | | | | | | | | | | | |
| carrier supports | | D | | | | | | | | | | | | | | | | | | | |
| carrier envelope | | | I | | | | | | | | | | | | | | | | | I | |
| hand-off I/O | | | | I | | | | | | | | D | | | | | | | | | |
| stocker load ports | | | | | | | | | | | | | | I | | | | | | | |
| **roller conveyor:** | | | | | | | | | | | | | | | | | | | | | |
| carrier rails | | | I | I | | | | | | | | | | | | | | | | | |
| carrier envelope | | | I | I | | | | | | | | | | | | | | | | | |
| equipment load ports | | | | | | | | | | I | | | | | | | | | | | |
| hand-off I/O | | | | | | | | | | | | D | | | | | | | | | |
| **PGV:** | | | | | | | | | | | | | | | | | | | | | |
| carrier supports | | D | | | | | | | | | | | | | | | | | | | |
| carrier envelope | | | I | I | | | | | | | | | | | | | | | | | |
| carrier handler | | | I | I | | | | | I | | | | | | | | | | | | |
| tool load port access | | | | | | | | | I | | | | | | | | | | | | I |
| docking features | | | | | | | | | | I | I | | | | | | | | | | |

| *Type of Product and its Components* | *SEMI M1.15, M8, or M28 (Wafer)* | *SEMI E57 (Kinematic Coupling)* | *SEMI E1.9 (Cassette)* | *SEMI E47.1 (FOUP)* | *SEMI M31 (FOSB)* | *SEMI E103 (Single-Wafer Box System)* | *SEMI E62 (FIMS)* | *SEMI E63 (BOLTS-M) and/or E92 (BOLTS-Light)* | *SEMI E15.1 (Load Port)* | *SEMI E64 (Cart Docking Interface)* | *SEMI E83 (PGV Docking Flange)* | *SEMI E84 (Carrier Handoff Parallel I/O)* | *SEMI E99 & E99.1 (Carrier ID Reader/Writer Comm.)* | *SEMI E85 (Stocker to Interbay Transport System)* | *SEMI E22.1 (Cluster- Tool End Effector)* | *SEMI E21.1 (Cluster-Tool Module Interface)* | *SEMI E25 & E26.1 (Cluster-Tool Access & Footprint)* | *SEMI E72 (Equipment Footprint, Height, and Weight)* | *SEMI G74 (Tape Frame)* | *SEMI G77 (Frame Cassette)* | *SEMI E110 (Indicator/Switch Placement)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **AGV or RGV:** | | | | | | | | | | | | | | | | | | | | | |
| carrier supports | | D | | | | | | | | | | | | | | | | | | | |
| carrier envelope | | | I | I | | | | | | | | | | | | | | | | I | |
| carrier handler | | | I | I | | | | | I | | | | | | | | | | | I | |
| tool load port access | | | | | | | | | I | | | | | | | | | | | | |
| hand-off I/O | | | | | | | | | | | | D | | | | | | | | | |
| **intrabay OHT vehicle:** | | | | | | | | | | | | | | | | | | | | | |
| carrier envelope | | | | I | | | | | | | | | | | | | | | | | |
| carrier handler | | | | I | | | | | | | | | | | | | | | | | |
| tool load ports | | | | | | | | | I | | | | | | | | | | | | |
| hand-off I/O | | | | | | | | | | | | D | | | | | | | | | |
| stocker load ports | | | | | | | | | | | | | | I | | | | | | | |
| height | | | | | | | | | | | | | | | | | | I | | | |
| **carrier stocker:** | | | | | | | | | | | | | | | | | | | | | |
| carrier supports | | D | | | | | | | | | | | | | | | | | | | |
| carrier envelope | | | I | I | | | | | | | | | | | | | | | | I | |
| carrier handler | | | I | I | | | | | | | | | | | | | | | | I | |
| floor based load ports | | | | | | | | | D | | | | | | | | | | | | |
| PGV interface | | | | | | | | | | D | | | | | | | | | | | |
| hand-off I/O | | | | | | | | | | | | D | | | | | | | | | |
| carrier ID reader | | | | | | | | | | | | | D | | | | | | | | |
| overhead load ports | | | | | | | | | | | | | | D | | | | | | | |
| height and weight | | | | | | | | | | | | | | | | | | D | | | |
| **carrier ID reader unit:** | | | | | | | | | | | | | | | | | | | | | |
| ID tags on carrier | | | I | I | | | | | | | | | | | | | | | | I | |
| volume in load port | | | | | | | | | I | | | | | | | | | | | | |
| **box opener/loader unit:** | | | | | | | | | | | | | | | | | | | | | |
| carrier supports | | D | | | | | | | | | | | | | | | | | | | |
| carrier envelope | | | I | I | | | | | | | | | | | | | | | | | |
| FOUP door opener | | | | | | | D | | | | | | | | | | | | | | |
| interface to rest of tool | | | | | | | | I | | | | | | | | | | | | | |
| load ports | | | | | | | | | D | | | | | | | | | | | | |
| PGV interface | | | | | | | | | | D | | | | | | | | | | | |
| hand-off I/O | | | | | | | | | | | | D | | | | | | | | | |
| carrier ID reader | | | | | | | | | | | | | D | | | | | | | | |
| height and weight | | | | | | | | | | | | | | | | | | D | | | |
| Indicator and switch | | | | | | | | | | | | | | | | | | | | | D |

| *Type of Product and its Components* | *SEMI M1.15, M8, or M28 (Wafer)* | *SEMI E57 (Kinematic Coupling)* | *SEMI E1.9 (Cassette)* | *SEMI E47.1 (FOUP)* | *SEMI M31 (FOSB)* | *SEMI E103 (Single-Wafer Box System)* | *SEMI E62 (FIMS)* | *SEMI E63 (BOLTS-M) and/or E92 (BOLTS-Light)* | *SEMI E15.1 (Load Port)* | *SEMI E64 (Cart Docking Interface)* | *SEMI E83 (PGV Docking Flange)* | *SEMI E84 (Carrier Handoff Parallel I/O)* | *SEMI E99 & E99.1 (Carrier ID Reader/Writer Comm.)* | *SEMI E85 (Stocker to Interbay Transport System)* | *SEMI E22.1 (Cluster- Tool End Effector)* | *SEMI E21.1 (Cluster-Tool Module Interface)* | *SEMI E25 & E26.1 (Cluster-Tool Access & Footprint)* | *SEMI E72 (Equipment Footprint, Height, and Weight)* | *SEMI G74 (Tape Frame)* | *SEMI G77 (Frame Cassette)* | *SEMI E110 (Indicator/Switch Placement)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **main part of process or metrology equipment:** | | | | | | | | | | | | | | | | | | | | | |
| substrate handler | I | | I | | | | | | | | | | | | D | | | | | | |
| box opener interface | | | | | | | | D | | | | | | | | | | | | | |
| tool controller | | | | | | | | | | | | | D | | | | | | | | |
| height and weight | | | | | | | | | | | | | | | | | | D | | | |
| **cluster tool central handler module:** | | | | | | | | | | | | | | | | | | | | | |
| substrate handler | I | | | | | | | | | | | | | | D | | | | | | |
| module interface | | | | | | | | | | | | | | | | D | | | | | |
| footprint and access | | | | | | | | | | | | | | | | | I | | | | |
| height and weight | | | | | | | | | | | | | | | | | | D | | | |
| **cluster tool process module:** | | | | | | | | | | | | | | | | | | | | | |
| process chamber | I | | | | | | | | | | | | | | I | | | | | | |
| module interface | | | | | | | | | | | | | | | | D | | | | | |
| footprint and access | | | | | | | | | | | | | | | | | D | | | | |
| height and weight | | | | | | | | | | | | | | | | | | D | | | |
| **wafer tape frame:** | | | | | | | | | | | | | | | | | | | | | |
| wafer contact | I | | | | | | | | | | | | | | | | | | | | |
| other features | | | | | | | | | | | | | | | | | | | D | | |
| **frame cassette:** | | | | | | | | | | | | | | | | | | | | | |
| wafer/frame contact | I | | | | | | | | | | | | | | | | | | I | | |
| other features | | | | | | | | | | | | | | | | | | | | D | |
| **back-end tool load port:** | | | | | | | | | | | | | | | | | | | | | |
| carrier envelope | | | | | | | | | | | | | | | | | | | | I | |

## 8 Related Documents[1]

Backend Global Joint Guidance for 300 mm Semiconductor Factories

Global Joint Guidance for 300 mm Semiconductor Factories

I300I Factory Guideline Compliance: Factory Integration Maturity Assessment for 300 mm Production Equipment

I300I Factory Guidelines

1 http://www.sematech.org/public/resources/300mm/guide.htm and http://www.sematech.org/public/resources/300mm/methods.htm

I300I Guidelines on 300 mm Process Tool Mechanical Interfaces for Wafer Lot Delivery, Buffering, and Loading

Integrated Minienvironment Design Best Practices

## RELATED INFORMATION 1

**NOTICE**: This related information is not an official part of SEMI E106 and is not meant to modify or supersede it in any way. Rather, these notes are provided primarily as a source of information to aid in the application of the standard. As such, they are to be considered as reference material only. The standard should be referred to in all cases.

R1-1 *Standards Endorsed by Users* — Section 8 lists documents in which the members of I300I and/or J300E have endorsed SEMI 300 mm standards or have specified methods for testing compliance with those standards.

# SEMI E108-0301
# TEST METHOD FOR THE ASSESSMENT OF OUTGASSING ORGANIC CONTAMINATION FROM MINIENVIRONMENTS USING GAS CHROMATOGRAPHY/MASS SPECTROSCOPY

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.

## 1 Purpose

1.1 The purpose of this standard is to define a test method for the determination of the outgassing organic contamination from minienvironments used for storage and transport of wafers using gas chromatography/mass spectroscopy (GC/MS).

1.2 This test method is intended as an alternative to SEMI E46. The main difference between SEMI E46 and this document is that SEMI E46 defines a test method which is based on ion mobility spectroscopy (IMS) as the measurement technique while this standard is based on gas chromatography/mass spectroscopy in combination with thermal desorption. Additionally, this test method provides a procedure for testing the outgassing of organic compounds in a complete minienvironment. The results of SEMI E46 and this document are given in different units.

## 2 Scope

2.1 The test method provided in this document is applicable to the assessment of the outgassing of organic contamination from minienvironments.

2.2 Gas chromatography/mass spectroscopy is chosen as the method to determine organic contamination because it is commonly used for characterization and quantification of organic compounds. In combination with thermal desorption, it provides a method for the identification of organic compounds in the atmosphere (i.e., inside the minienvironment) as well as directly from source materials, and transferred contaminants. This method can also be used to evaluate materials and processes used in semiconductor industry.

2.3 This test method is based on ASTM F1982.

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 health practices and determine the applicability or regulatory limitations prior to use.

## 3 Limitations

3.1 The test methodologies, metrics and applications provided in this standard are limited by the following constraints:

3.1.1 The specific recovery of compounds by the proposed standard method strongly depends on the setup of the apparatus used. This has been taken into account by the use of the "reference-cocktail", see Section 9.2.

3.2 Identification of the source of organic compounds inside the minienvironment is out of the scope of this test method. For a procedure for the analysis of outgassing organic compounds from individual materials using gas chromatography/mass spectroscopy, see IDEMA M11-99.

3.3 This test method does not provide a procedure how to use the obtained data for assessing the risks that come from individual compounds.

## 4 Referenced Standards

4.1 *SEMI Standards*

SEMI E46 — Test Method for the Determination of Organic Contamination from Minienvironments

SEMI F21 — Classification of Airborne Molecular Contaminant Levels in Clean Environments

4.2 *ASTM Standard*[1]

ASTM F1982 — Standard Test Methods for Analyzing Organic Contaminants on Silicon Wafer Surfaces by Thermal Desorption Gas Chromatography.

4.3 *IDEMA Standard*[2]

IDEMA M11-99 — General Outgas Test Procedure by Dynamic Headspace Analysis

1 American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, website: www.astm.org

2 International Disk Drive Equipment and Materials Association, 3255 Scott Blvd., Suite 2-102, Santa Clara, CA 95054-3013, website: www.idema.org

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

## 5 Terminology

5.1 *analytical environment* — environment where all analytical measurements are taking place.

5.2 *headspace sampling* — in this standard defined as: collecting volatile organic compounds in an enclosed volume by means of a silicon wafer or silicon wafer chips.

5.3 *minienvironment* — A localized environment for transport and storage created by an enclosure to isolate the product from contamination and people.

5.4 *sample* — wafer or wafer chips used for the headspace sampling of organic contaminants.

5.5 *static storage conditions* — conditions excluding any active movement of test specimens.

5.6 *thermal desorption tube* — Analytical equipment capable of collecting organic compounds of interest (i.e., adsorbent filled glass tube).

5.7 *wafer* — Object made of semiconducting material to be processed, handled or stored in the minienvironment to be tested (i.e., prime or processed silicon wafer).

## 6 Summary of Method

6.1 This test method comprises storage tests of wafers in minienvironments under static storage conditions. The contamination is directly measured from the silicon wafer 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.

6.2 The setup for each test comprises an analytical equipment in the analytical environment as well as a test equipment in the test environment. Each environment has to fulfill the following requirements:

6.2.1 *Analytical Environment* — shall be clean enough with respect to airborne organic contamination: recommendation is less than 100 pptM for organic compounds with boiling points > 150°C (Class MC-100, according to SEMI F21).

6.2.2 *Test Environment* — shall equal the environment in which the test specimen will be used.

6.3 Silicon wafers are placed in the minienvironment or used for headspace sampling experiments. These wafer samples are then analyzed by gas chromatography/mass spectrometry to determine the amount of contaminants.

6.4 The wafers or wafer chips to be used for the test method are decontaminated as described in ASTM F1982 for bare silicon wafers. The surface condition of the wafer (hydrophobic or hydrophilic) has to be adjusted in a reproducible way and has to be the same for all comparative measurements.

6.5 The wafer or the wafer chips are placed in the minienvironment and are left there under static conditions for the chosen static storage time (depending on the intended use of the minienvironment to be tested, a time between 1 h and 28 d may be used). When loaded into the minienvironment the wafer may have a temperature which reflects production circumstances (i.e., 80°C when unloading from furnace processes). In some situations wafers may be exposed to severe thermal conditions. The minienvironment should be evaluated under the conditions exposed to. Be sure that the material to be tested does not undergo phase transitions under the chosen temperature conditions.

6.6 After the static storage test period, the wafer is returned to the analytical equipment and the organic contamination on the wafer is measured immediately.

6.7 The quantitative value for the total amount of outgassed and adsorbed organics from the minienvironment is calculated as the difference between the detected amount of contamination on a blank sample vs. the amount on the exposed sample.

## 7 Interferences

7.1 The presence of organic contamination in the atmosphere of the test environment may lead to a significant contribution to the detected total amount of organic compounds on the test wafers or wafer chips. Care has to be taken when subtracting the blank value from the test value. Transport times from test environment to analytical environment have to be as short as possible.

## 8 Apparatus

8.1 For the analysis of organic compounds on wafers a gas chromatography/mass spectroscopy apparatus with thermal desorption unit is required: A gas chromatography (GC) instrument, which utilizes a capillary column to separate a wide variety of organic compounds, combined with mass spectrometer (MS). A thermal desorption unit is used to desorb organics from sample thermal desorption tubes and collect them in a trap. Two types of trapping may be used:

a) cooling the trap down to a minimum of -150°C does not require any adsorbent (glass wool may be used) or

b) a Tenax® filled trap has to be cooled down to a minimum of -25°C.

8.1.1 The thermal desorption unit is coupled to the gas chromatography instrument via a heated transfer line. This apparatus may be used directly for the desorption from wafer chips which are put in empty glass (or stainless steel) thermo desorption tubes (method A).

8.1.2 A desorption unit for complete wafers is specified in ASTM F1982. In this case sample thermal desorption tubes packed with adsorbent have to be used to trap compounds desorbed from the wafer. These thermal desorption tubes are analyzed within the thermal desorption unit (method B).

8.2 The analysis of outgassing organic contamination from minienvironments requires an extremely sensitive analytical equipment. Recovery and limit of detection for the different classes of compounds must be evaluated carefully in order to ensure reliable results.

## 9 Reagents and Materials

9.1 For the materials used for handling and transport of wafers clean, decontaminated equipment has to be used, e.g. tweezers heated in a propane flame. Refer to the reagent and materials described in SEMI E46 and ASTM F1982.

9.2 *Test Mixture* — For the calibration of equipment and the quantification of the amount of contamination a test mixture (”cocktail”) is used. This mixture was chosen in order to give an ”average” over typical substance classes present in semiconductor production lines, which have high sticking factors to the wafer surface. The response factor of the MS-detection for organics varies significantly. As this is true for all contaminants, the method gives a realistic trustworthy quantitative correlation to a ”typical average compound mixture” of contaminants on wafer surfaces.

9.3 *Preparation of Test Mixture*

9.3.1 The mixture consists of triethyl phosphate, ε-caprolactam, palmitic acid and diethylhexyl phthalate each 0.5 µg/µl in isooctane (as solvent). The preparation has to be done according to SEMI E46.

NOTE 2: A similar test mixture is suggested by the working group *WG 031* of the *Institute for Environmental Science and Technology* (IEST)

## 10 Safety Precautions

10.1 All preparation and analytical work has to be done according to local safety regulations.

## 11 Preparation of Minienvironment and Sample

11.1 *Minienvironment* — The minienvironment to be tested has to be used as received from the supplier. A cleaning step can be added but there must be no contribution from the cleaning procedure to the outgassing of organic compounds from the minienvironment. The cleaning method has to be defined by the supplier or agreed upon between supplier and user of the tested minienvironment.

11.2 *Sample* — The wafers shall be made organic-free before using them to monitor organic contamination. The surface condition of the wafer (hydrophobic or hydrophilic) has to be adjusted in a reproducible way and has to be the same for comparative measurements. Refer to SEMI E46 and ASTM F1982.

## 12 Procedure

12.1 The procedure described below is used for obtaining the baseline value of the method (method blank) as well as the test value for outgassing organic compounds of the minienvironment within a defined static storage time (storage time $t_S$ = 1 h - 28 d).

12.1.1 Choose that static storage time according to the intended use of the minienvironment (i.e., if the maximum sit time of wafers in a process where the minienvironment is to be used is 4 h then choose a static storage time of 4 h). If no static storage time related to processes can be defined, a recommended value for the first static storage time is 1 day.

NOTE 3: Composition of adsorbed compounds may vary with static storage time.

12.2 For transport store the wafers or wafer chips used for testing in decontaminated, organic-free petri-dishes wrapped in organic-free aluminum foil. Refer to SEMI E46.

12.3 *Loading Procedure*

12.3.1 *For tests at room temperature:* open a minienvironment to be tested and load it with a decontaminated wafer using decontaminated handling tools (i.e., tweezers). Default storage location is the center slot of the minienvironment. Close the minienvironment. Leave the minienvironment closed for the chosen static storage time.

12.3.2 *For tests at elevated temperatures using a wafer furnace:* place the decontaminated wafers in a clean furnace used for production processes and heat the wafers under inert gas to a temperature > 120°C. Turn off the heating. When the temperature of the furnace has reached (90±10)°C open the minienvironment to be tested and fully load it with the hot wafers from the furnace. Close the minienvironment. Leave it closed for the chosen static storage time. For analysis use only one wafer. Default wafer is the one in the center slot.

12.3.3 *For tests at elevated temperatures using a heating chamber*: open the minienvironment to be tested and load it with a decontaminated wafer using decontaminated handling tools (i.e., tweezers). Default location is the center slot. Close the minienvironment. Wrap the minienvironment with decontaminated aluminum foil. Place the minienvironment in an inert and clean heating chamber heated to 70°C. Leave it for 1 h and then remove it from the heating chamber and place it at the test minienvironment. Leave it there closed for the chosen static storage time.

NOTE 4: The purpose of the aluminum foil is to prevent direct contact between the recirculating hot air inside the heating chamber and the minienvironment.

12.4 *Unloading Procedure* — Open the minienvironment and unload the wafer using decontaminated handling tools into decontaminated petri-dishes and wrap them into organic-free aluminum foil. Transport the wafer immediately to the measurement equipment and analyze the organic contamination on the wafer according to the standard ASTM F1982.

12.5 *Method Blank* — Perform the test sequence using a container made completely of glass or quartz instead of the minienvironment. Use the same static storage time for the method blank but perform this blank test at room temperature. The container has to be decontaminated with respect to organics inside by heat treatment (refer to SEMI E46). With this blank method the baseline contribution from the cleanroom air on the adsorption of organic contamination on the silicon wafer surface is determined.

12.6 *Analyzing Procedure* — Put the wafer or wafer chips in the precleaned desorption unit or thermal desorption tube and heat it for 10 min to a minimum of 275°C (but 400°C is better). The desorbed contaminants have to be trapped directly with the cold trap of the thermodesorption unit (method A) or first by adsorbent filled desorption tubes and then by the cold trap (method B). Desorption parameters for adsorbent filled desorption tube and cold trap may be taken from ASTM F1982 (see also Section 12.6.1).

12.6.1 The substances desorbed should be separated by an appropriate column temperature program. A recommended temperature program for standard analysis uses a polydimethylsiloxane/polydiphenylsiloxane (95/5) coated column (30 m × 0.25 mm × 0.25 µm), heated from 50°C to 250°C at a rate of 10°C/min followed by a temperature hold at 250°C for 10 min. Column flow should be about 1 ml/min He at constant flow.

12.6.2 All parameters (thermo desorption unit, gas chromatograph, mass spectrometer) should be set to yield the recommended detection limits and recovery rates (see Calibration Procedure Section 13.2).

12.7 *Materials Testing* — Materials testing can be done, using the sample preparation described in SEMI E46, but using gas chromatography/mass spectroscopy instead of IMS for the analysis of contaminants on the test wafers or wafer chips.

12.8 Perform the procedure for calibration, method blank and test (including sample preparation) in triplicate in order to obtain mean value and standard deviation for the analysis.

## 13 Calibration and System Performance

13.1 *Calibration* — The test mixture (2 µl liquid, equals 1 µg of each substance; see Section 9.3) is applied to the wafer or wafer chips as described in SEMI E46. The so produced reference wafer or wafer chips are handled in the same way as the samples. That means, they are put in the precleaned desorption unit or thermal desorption tube and heated for 10 min to minimum 275°C (but 400°C is better) and so on as described in Section 12.6.

13.2 *System Performance* — All parameters (thermodesorption unit, gas chromatograph, mass spectrometer) should be set to yield the specified detection limits and recovery rates (method B) for the components of the reference mixture. The limit of detection (3σ) must equal or be better than 250 ng for each of the four reference substances. The standard deviation (inaccuracy) of the calibration must be ≤ 10%. Sample measurements are not allowed, unless these requirements are fulfilled. For sample measurements the same parameters as for the calibration measurements have to be used.

## 14 Quantification

14.1 *Integration* — After the analysis measure the surface area ($A_s$) of the tested wafer or wafer chips. Summing up all the peak areas from gas chromatography/mass spectroscopy chromatogram of the wafer or wafer chips gives the total integral ($I_s$). Determine the total integral ($I_b$) of the blank wafer and the total integral of the four peaks of the gas chromatography/mass spectroscopy chromatogram of the test mixture ($I_r$) with the same technique.

14.2 *Calculation*

$$T_c = \left( \frac{I_s}{A_s} - \frac{I_b}{A_b} \right) \times \frac{W_r}{I_r}$$

where

| | | |
|---|---|---|
| $\mathbf{T_c}$ | = | total of organic contaminants, [ng test mixture equivalent/cm$^2$] |
| $\mathbf{I_s}$ | = | total integral from gas chromatography/mass spectroscopy chromatogram of the sample |
| $\mathbf{I_b}$ | = | total integral from gas chromatography/mass spectroscopy chromatogram of the method blank |
| $\mathbf{I_r}$ | = | total integral from gas chromatography/mass spectroscopy chromatogram of the peaks of the test mixture |
| $\mathbf{W_r}$ | = | total weight amount of test mixture compounds applied to wafer [ng] { = 4000 ng} |
| $\mathbf{A_s}$ | = | total area (cm$^2$) of the sample investigated (wafer or wafer chips) |
| $\mathbf{A_b}$ | = | total area (cm$^2$) of the method blank (wafer or wafer chips) |

## 15 Reporting Results

15.1 The essential results of carrying out the procedure are to be summarized in a data sheet for each experiment. The data sheet has to comprise the following information:

General data:

- Date
- Operator

Environmental data:

- Cleanroom class of analytical environment (cf. SEMI F21)
- Cleanroom class of test environment

Data concerning minienvironment:

- Type
- Manufacturer
- ID
- pretreatment (cleaning, etc.)

Data concerning sample:

- Manufacturer
- Type (resistivity, dopant)
- Surface condition (hydrophilic, hydrophobic)
- Decontamination procedure

Data concerning *analytical equipment (gas chromatography/mass spectroscopy, thermal desorption, wafer furnace or heating chamber)*:

- Manufacturer
- Type
- Limit of detection and standard deviation of calibration procedure

Data concerning *static storage test*:

- Storage temperature [°C]
- Storage relaive humidity [%]
- Time of static storage test [h]
- Wafer furnace or heating chamber used (if applicable)

Data concerning *storage test result*:

- Slot location of wafer
- Total of organic contaminants $T_c$
- Standard deviation of measurement (if applicable)

**NOTICE:** SEMI makes no warranties or representations as to the suitability of the standards set forth herein for any particular application. The determination of the suitability of the standard is solely the responsibility of the user. Users are cautioned to refer to manufacture's instructions, product labels, product data sheets, and other relevant literature, respecting any materials or equipment mentioned herein. These standards are subject to change without notice.

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# SEMI E110-1102
# GUIDELINE FOR INDICATOR PLACEMENT ZONE AND SWITCH PLACEMENT VOLUME OF LOAD PORT OPERATION INTERFACE FOR 300 mm LOAD PORTS

This guideline was technically approved by the Global Physical Interfaces and Carriers Committee and is the direct responsibility of the Japanese Physical Interfaces and Carriers Committee. Current edition approved by the Japanese Regional Standards Committee on July 19, 2002. Initially available at www.semi.org October 2002; to be published November 2002. Originally published November 2001.

## 1 Purpose

1.1 This guideline defines the zones and volumes in which load port status indicators and load port operation switches should be placed. The purpose of this guideline is to give a similarity in the placement of them on a 300 mm load port. This guideline only defines the zones and volumes for them and the exact placement of them within these zone and volumes are at the direction of the load port suppliers.

1.2 The zones or volumes may be defined more precisely by standardization improvement on load port design and good unification of load port operation among device manufactures. This guideline may be improved to be a specification after this effort.

## 2 Scope

2.1 This guideline defines following recommended specifications for 300 mm load port.

- Indicator placement zone in which load port status indicators should be placed.
- Switch placement volume in which load port operation switch should be placed.

2.2 This guideline covers the specifications for both fixed buffer equipment and internal buffer equipment.

2.3 This guideline is intended to set an appropriate level of specification that places minimal limits on innovation while ensuring modularity and inter-changeability at all mechanical interfaces. Only the physical interfaces for the load port are specified; no materials requirements, micro-contamination limits, use of or logic associated with the defined physical features are given in this specification.

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

## 3 Referenced Standards

3.1 *SEMI Standards*

SEMI E15 — Specification for Tool Load Port

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

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

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

SEMI E87 — Specification for Carrier Management (CMS)

SEMI E101 — Provisional Guide for EFEM Functional Structure Model

NOTE 1: 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 bisects the wafers and that is perpendicular to both the horizontal and facial datum planes (as defined in SEMI E57).

4.1.2 *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).

4.1.3 *fixed buffer equipment* — production equipment that has only fixed load ports and no internal buffer for carrier storage. Substrates are loaded and unloaded directly from the carrier at the load port for processing (as defined in SEMI E87).

4.1.4 *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).

4.1.5 *indicator placement zone* — a zone in which load port status indicators are placed.

4.1.6 *internal buffer equipment* — equipment that uses an internal buffer (as defined in SEMI E87).

4.1.7 *load port operation interface* — any indicator (e.g. lamp, LED) to visualize status information of a load port to an operator and/or any switch to be used for manual handoff operation.

4.1.8 *load port operation switch* — any switch to be used for manual handoff operation.

4.1.9 *load port status indicator* — any indicator (e.g. lamp, LED) to visualize status information of a load port to an operator.

4.1.10 *switch placement volume* — a volume in which load port operation switch is placed.

## 5 Requirements

5.1 *Indicator placement zone*

5.1.1 *Indicator Placement Zone for a Load Port per SEMI E15.1 Option 1* — It is recommended that load port status indicators should be positioned within a zone given by x400, z400, and z401. The exact placement of them within this zone is at the direction of the load port supplier. They may be located at or behind (away from the operator) the equipment boundary. Clearances required by SEMI E15.1 cannot be violated.

NOTE 2: The indicator placement zone is not an exclusion zone. No assumption can be made that this zone needs to be kept empty by the load port supplier. Furthermore, no assumption can be made that a load port must have a physical surface representing the indicator placement zone.

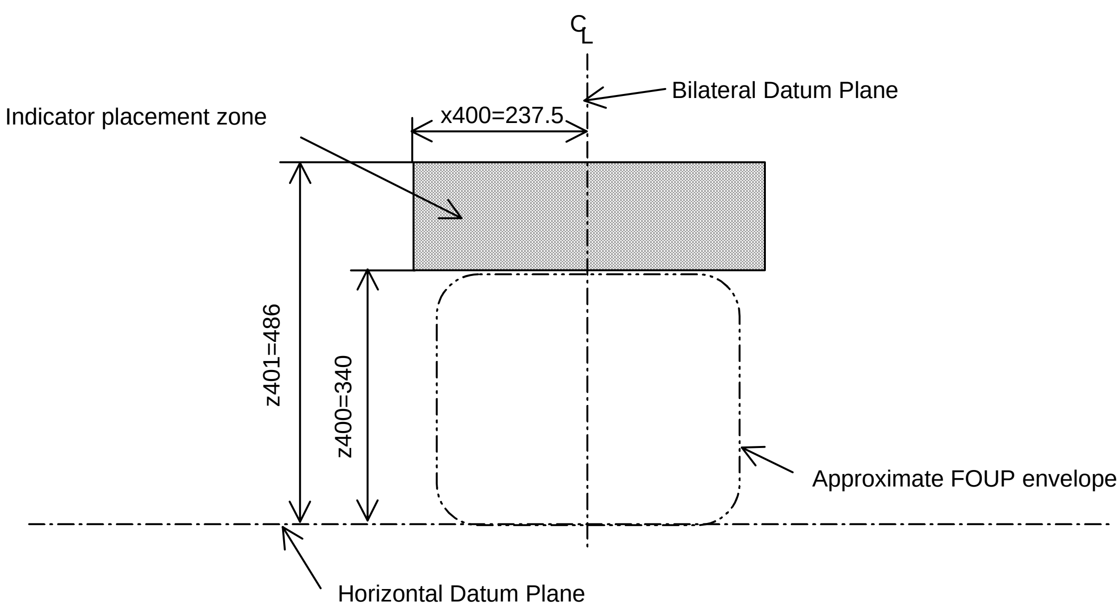


**Figure 1**
**Indicator Placement Zone for a Load Port Per SEMI E15.1 Option 1**