INSTITUTE OF ENVIRONMENTAL SCIENCES AND TECHNOLOGY

Contamination Control Division Recommended Practice 028.1

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Minienvironments

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1 SCOPE AND LIMITATIONS

1.1 Scope

The purpose of this document is to provide a framework for describing minienvironments for microelectronics and similar applications.

Applications, planning, design, and evaluation are discussed in detail.

This Recommended Practice is intended to stimulate discussion of specifications and configurations for a specified application between the supplier and customer. This Recommended Practice does not address microbiological issues or applications.

1.2 Limitations

This Recommended Practice is limited to a discussion of the design characteristics and operating characteristics of minienvironments and other locally controlled environments. Process equipment design falls outside the scope of this document.

This document does not supersede specific requirements established by recognized national or international regulating bodies. Certain specific hazardous materials, such as radioactive materials and genetically altered organisms, and certain toxic materials are not specifically addressed in this document. Users of these substances should augment this document with industry-specific publications.

2 REFERENCES

2.1 Institute of Environmental Sciences and Technology (IEST)

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IEST-RP-CC006.2: Testing Cleanrooms

IEST-RP-CC008-84: Gas-Phase Adsorber Cells

IEST-RP-CC012.1: Considerations in Cleanroom Design

IEST-RP-CC022.1: Electrostatic Charge in Cleanrooms and Other Controlled Environments

IEST-RP-CC034.1: HEPA and ULPA Filter Leak Tests

2.2 American National Standards Institute (ANSI)

Website: www.ansi.org

ANSI C63.14-1992 Dictionary of Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)

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2.3 American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)

Website: www.ashrae.org

2.4 ASTM International

Website: www.astm.org

ASTM D257 Standard Test Method for DC Resistance or Conductance of Insulating Materials

ASTM E595-93 Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment

2.5 European Committee for Standardization (CEN)

Website: www.cenorm.be

EN 55011 Limits and Methods of Measurement of Radio Disturbance Characteristics of Industrial, Scientific and Medical (ISM) Radio-Frequency Equipment

EN 50082-1:1992 Electromagnetic Compatibility—Generic Immunity Standard, Part 1: Residential, Commercial and Light Industry

EN 50082-2:1994 Electromagnetic Compatibility—Generic Immunity Standard, Part 2: Industrial Environment

2.6 Factory Mutual Research Corporation (FMRC)

Website: www.fmglobal.com/default.asp

FM 4910 FMRC Clean Room Materials Flammability Test Protocol

2.7 Illumination Engineering Society of North America (IESNA)

Website: www.iesna.org

IESNA Lighting Handbook

2.8 International Organization for Standardization (ISO)

Available from IEST at www.iest.org.

ISO 14644-1 Cleanrooms and associated controlled environments—Part 1: Classification of airborne particulates

2.9 Military

Available from the Defense Information Systems Agency (DISA) at www.disa.mil and from other sources.

MIL-HDBK-263B Electrostatic Discharge Control (ESD) Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices) (Metric)

2.10 National Association of Corrosion Engineers (NACE)

Website: www.nace.org

National Association of Corrosion Engineers (NACE) Coatings and Linings Handbook.

NACE Corrosion Engineers Reference Handbook.

2.11 National Fire Protection Association (NFPA)

Website: www.nfpa.org

NFPA-70: National Electric Code

2.12 Semiconductor Equipment and Materials International (SEMI)

Website: www.semi.org

SEMI E14-93 Measurement of Particle Contamination Contributed to the Product from the Process or Support Tool

SEMI E33-94 Specification for Semiconductor Manufacturing Facility Electromagnetic Compatibility

SEMI E43-95 Recommended Practice for Measuring Static Charge on Objects and Surfaces

SEMI F21-95 Classification of Airborne Molecular Contaminant Levels in Clean Environments

SEMI S2-0200 Environmental, Healthy, and Safety Guidelines for Semiconductor Manufacturing Equipment

SEMI S8-95 Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment

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2.13 Underwriters Laboratories (UL)

Website: www.ul.com

UL-900 Safety Standards for Air Filter Units

2.14 Other

Hinds, W.C. *Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particle*. New York: Wiley & Sons, 1982.

3 TERMS AND DEFINITIONS

adsorption
process by which one substance is attracted to and held on the surface of another; one substance adheres to the surface of the other

aerosol
gaseous suspension of solid or liquid material, usually between 0.001 μm and 1000 μm in diameter

airflow
In the context of this document, movement of all gaseous environmental media (e.g., air, nitrogen, argon, etc.).

ambient
environment external to the minienvironment

box
protective portable container for a cassette and/or contamination-sensitive products

cassette
open structure that holds one or more contamination-sensitive products

certification
statement by a testing agency that a minienvironment has been tested in accordance with the latest revision of established specifications and that the requirements of the specifications have been achieved

chemisorption
type of adsorption having most of the characteristics of a chemical reaction between a reactant molecule and the solid

condensable
substance (other than water) typically having a boiling point above room temperature at atmospheric pressure, capable of condensation on a clean surface

contaminant
anything that can adversely affect product, process, or people

dopant
chemical element that modifies the electrical properties of a semiconductor material

electromagnetic compatibility (EMC)
ability of an electronic system or device to: 1) function properly in its intended electromagnetic environment, and 2) not be a source of electromagnetic pollution to its environment; where the electromagnetic environment is composed of both radiated and conducted energy, EMC has two aspects: susceptibility and emission

electromagnetic interference (EMI)
conducted or radiated electrical disturbances that can interfere with equipment operation; these disturbances can occur anywhere in the electromagnetic spectrum, from less than 10 Hz to cosmic rays, including radio, light, and x-rays

electrostatic discharge (ESD)
transfer of electrostatic charge between bodies at different electrostatic potentials

enclosure
physical barrier or barriers separating the localized environment and its surroundings

flow visualization
method for demonstrating patterns of airflow, either physically (using fog test, aerosol smoke test, strings, or threads) or by computational fluid dynamics

input/output (I/O) device
means of transferring contamination-sensitive materials into and out of a minienvironment

integration
integration of the minienvironment into the entire production system (including process materials, process equipment, materials-handling equipment, people, cleanroom, etc.)

inert
chemically non-reactive with the products or materials at hand or in use

isolation
separation of a process or object from the ambient environment

mean time between failures (MTBF)
average time (in hours) equipment performed intended function prior to failure

minienvironment
localized environment created by an enclosure to isolate a product or process from the surrounding environment

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monitor wafer
semiconductor wafer used as a witness plate

monitoring
routine measurement of relevant conditions (airborne particles, surface particles, temperature and humidity, differential pressure, airflow velocity and directionality, etc.)

outgassing
liberation of a gas from any material other than by a change of state

particle
object that is solid, liquid, or both, usually between 1 nanometer and 1 millimeter in size

particle deposition rate
number of particles deposited on a surface per unit of time

physisorption
attraction of an adsorbate, e.g. contaminants, to the surface of an adsorbent caused mainly by van der Waals forces and electrostatic forces

pod
box containing a cassette of wafers that is used in conjunction with a standard mechanical interface (SMIF); the box isolates the cassette of wafers and maintains the integrity of the minienvironment

precision
closeness of agreement between values obtained by repeated measurements of the same quantity under the identical conditions; also known as *repeatability* or *reproducibility*

radio-frequency interference (RFI)
electromagnetic radiation emitted by electrical circuits carrying rapidly changing signals as a by-product of their normal operation, and that causes unwanted signals (interference or noise) to be induced in other circuits

relative humidity
ratio of the amount of water vapor in the air (at a specific temperature) to the maximum amount that the air could hold at that temperature, expressed as a percentage

resolution, particle size
capability of a particle-sizing device to discriminate between particles that are similar in size; expressed as the ratio of the minimum size differential required to indicate a size change to the size of the particle being measured

standard mechanical interface (SMIF)
mechanical device that transports a cassette of wafers into and out of a minienvironment

thermophoresis
movement of particles in a thermal gradient; can induce significant differences between airflow and particle velocity

triboelectric charging
electrostatic charging following the mechanical separation of solids or the separation of solids from fluids

unidirectional airflow
air that flows in a single pass in a single direction through a cleanroom or clean zone with generally parallel streamlines; formerly referred to as *laminar airflow*

witness plate
surface used to collect contaminants deposited from the environment; typically selected to simulate particular products (examples include silicon wafers, microscope plates, membrane filters, and glass photomask substrates)

4 APPLICATIONS AND CONCEPTS

4.1 Overview

Minienvironments can be specified and constructed in many styles and configurations. These configurations may range from the extremely simple laminar hood with direction shields to stand-alone, temperature- and humidity-controlled, ultra-clean chambers with inert recirculating gases and automated I/O mechanisms. The type and location depend on:

- Product contamination control requirements
- Plans for automation and product-handling
- New installation versus retrofit
- Economics
- Environmental control tolerances
- Safety issues

4.2 Use of Minienvironments

Minienvironments may be used to either protect a product from people or the environment, or to protect people and the environment from the product or process.

4.2.1 Protection of the product from people or the environment

Minienvironments may be used to protect contamination-sensitive products by isolating them from contaminants in the ambient environment. These contaminants may be environmental, the result of nearby production operations, or the result of personnel activity. The application of a specific minienvironment design to a given

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process should be evaluated based on its ability to control environmental parameters that are critical to process outcome, or provide protection of personnel from hazards that originate within the process, or both. Environmental parameters that may impact process outcome include aerosols, gaseous contaminants, temperature, humidity, pressure, vibration, electrostatic discharge, and electromagnetic radiation. Aerosols may be organic or inorganic in nature. Gas-phase contaminants may be corrosive, flammable, or toxic and may originate from the external environment or the process itself.

4.2.2 Protection of people or the environment from the product or process

Minienvironments may be used to protect people, the environment, or both, by isolating the hazardous products or processes from the surrounding environment. Process hazards that should be contained by the minienvironment include potent and toxic dusts, vapors, or gases; and nuclear and electromagnetic radiation.

4.3 Microelectronics Production Applications

Process equipment may be completely contained within the enclosure or the enclosure may be limited to the equipment load/unload interface only. In many cases the minienvironment is an integral part of the process tool.

The process technology relies on a physical barrier that may or may not be airtight. In non-airtight applications, isolation is accomplished by differential pressure, or airflow control, or both.

Some examples of environmental parameters that are critical to process outcome for various applications and specific unit operations are shown in Table 1.

4.4 Characteristics of Minienvironments

See Table 2.

4.4.1 Product environment

A number of design characteristics may be used to describe minienvironments.

Airflow through the minienvironment may be provided by the facility supply system (Figure 2) or by an integral fan (Figure 1 and Figure 3).

Facility-supplied minienvironments:

- have unidirectional flow shields.
- tie into an existing filter ceiling and air-handling systems.
- follow room ambient temperature and humidity levels.
- may be inflexible with respect to equipment relocation.
- are generally not conducive to equipment size modifications.
- may provide several orders of magnitude improvement in particle cleanliness levels.

Self-contained minienvironments typically (internal fan)

- are free standing with respect to existing cleanroom air-handling and structural systems.
- may control temperature and humidity independent of ambient room levels.
- are flexible with respect to equipment relocations.
- may provide several orders of magnitude improvement in particle cleanliness levels.

Other controlled environments may include inert atmosphere or vacuum environments.

4.4.2 Airflow path

Airflow may be either open- or closed-loop, depending on the return path. In open systems, the return path allows uncontrolled mixing with the external environment (Figure 1 and Figure 2). Closed systems are recirculating, returning air directly back to the supply source (Figure 3).

Open-loop systems typically use air. Closed-loop systems may use air or other gases that might include nitrogen, carbon dioxide, argon, or another gas. Closed-loop systems are capable of providing a higher degree of isolation and control than open-loop systems.

In semiconductor applications, closed-loop systems utilizing inert gases can be used to shield the product from ambient gas-phase contaminants including moisture, carbon monoxide, oxygen, and hydrocarbons.

Closed-loop systems may result in gas-phase contaminant build-up, the result of outgassing from the product, the tooling, or hardware components.

4.4.3 Environmental control

Minienvironments may independently control various environmental conditions relative to the external environment or they may simply track the external conditions. Typically, controlling systems are closed-loop

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