SEMI S14-0200
SAFETY GUIDELINES FOR FIRE RISK ASSESSMENT AND MITIGATION FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

These safety guidelines were technically approved by the Global Environmental Health and Safety Committee and are the direct responsibility of the North American Environmental Health and Safety Committee. Current edition approved by the North American Regional Standards Committee on September 3 and December 15, 1999. Initially available on SEMI OnLine February 2000; to be published February 2000.

1 Purpose

1.1 This document provides considerations to the manufacturers of semiconductor manufacturing equipment that will assist them in assessing and mitigating the risk to equipment and product associated with fire and combustion by-products.

1.2 Although these guidelines are written in the form of an assessment tool, they are intended for use throughout the design and development of semiconductor manufacturing equipment.

1.3 These guidelines may also be used by the users of such equipment and by other interested parties to assess and compare the described risks of various equipment designs or in the design and evaluation of ancillary equipment or modifications.

1.4 These guidelines are not intended to specify which techniques (e.g., selection of materials or detection systems) are to be used to mitigate fire risk. These guidelines do, however, recommend that the traditional risk management hierarchy of elimination, engineering controls, administrative controls, warning and work practices be followed.

1.5 The appropriate application of these guidelines will result in a report which identifies, analyzes and assesses residual fire risks.

2 Scope

2.1 These guidelines apply to equipment used to manufacture, measure, assemble, and test semiconductor products which is intended to be located in cleanrooms used for semiconductor manufacturing processes or areas within their recirculation airstream. They apply to all of the components of the equipment, as described herein.

NOTE 1: This document is not limited to the structural or large-area components of equipment.

2.2 This document applies to fire risks originating within the subject equipment that may result in damage to it, other equipment, products, or the facility.

2.3 This document identifies considerations for assessing the fire risk of semiconductor manufacturing equipment, means of categorizing the risks, and means of mitigating the risks.

2.4 These safety guidelines do not purport to address all of the safety issues associated with its use. It is the responsibility of the users of these safety guidelines to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3 Limitations

3.1 These guidelines do not establish acceptance criteria for residual risk.

3.2 This document recommends a hierarchy of approaches (e.g., elimination of a hazard is preferable to an engineering control) but neither prescribes which specific risk mitigation methods (e.g., change of material or elimination of an ignition source) are to be used nor ranks their relative merit.

3.3 These guidelines apply to the protection of property; they do not apply to the protection of personnel.

NOTE 2: Protection of personnel from fire risk is within the scope of SEMI S2.

3.4 This document applies to equipment in its scope when the equipment is used in the environment specified by the equipment supplier. Specifically, it does not apply to the behavior of equipment when it is subject to an external fire.

3.5 This document is not intended to be used to assess compliance with regulatory requirements, nor is it intended to be adopted as regulation.

3.6 Because of these limitations, it may be appropriate for purchasers of equipment to specify the applicable codes and standards and the acceptable level of residual risk.

NOTE 3: Applicable regional, and national codes, international regulations, and the equipment manufacturer's and user's requirements must also be considered. When a conflict exists, the regional and national codes take precedence.

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4 Referenced Standards

4.1 *SEMI Standards*

SEMI E70 — Guide for Tool Accommodation Process

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

SEMI S7 — Safety Guidelines for Environmental, Safety, and Health (ESH) Evaluation of Semiconductor Manufacturing Equipment

SEMI S10 — Safety Guideline for Risk Assessment

4.2 *NFPA Documents* [1]

National Fire Protection Association: NFPA 12 — Standard on Carbon Dioxide Fire Extinguishing Systems

National Fire Protection Association: NFPA 13 — Standard for the Installation of Sprinkler Systems

National Fire Protection Association: NFPA 72 — National Fire Alarm Code

National Fire Protection Association: NFPA 2001 — Standard on Clean Agent Fire Extinguishing Systems

4.3 *Factory Mutual Document*[2]

Factory Mutual Research Corp. Standard 4910 — Clean Room Materials Flammability Test Protocol

4.4 *Underwriters Laboratory Documents*[3]

Underwriters Laboratory Standard 94 — Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

Underwriters Laboratories Standard 746A — Polymeric Materials - Short Term Property Evaluations

Underwriters Laboratories Standard 746B — Polymeric Materials - Long Term Property Evaluations

Underwriters Laboratories Standard 746C — Polymeric Materials - Use in Electrical Equipment Evaluations

NOTE 4: As listed or revised, all documents cited shall be the latest publications of adopted standards.

5 Terminology

5.1 *abort switch* — a switch which, when activated, interrupts the activation sequence of a detection or suppression system.

5.2 *accredited testing laboratory* — an independent organization dedicated to the testing of components, devices, or systems; competent to perform evaluations based on established safety standards and recognized by a governmental or regulatory body.

5.3 *cleanroom* — a confined area in which the humidity, temperature, particulate matter, and contamination are precisely controlled within specified parameters (SEMI E70).

5.4 *combustible liquid* — a liquid that will burn and has a flash point at or above 37.8°C (100°F).

5.4.1 For the purpose of this guideline, a combustible liquid, when used by a system capable (under normal or single-fault conditions) of heating it above its flash point, is considered a flammable liquid.

5.5 *combustible material* — for the purpose of this document, a combustible material is any material which does not meet the definitions in this section for noncombustible materials.

NOTE 5: A list of criteria, guidelines and standards that may be used to evaluate the fire properties of materials is included in Appendix 2.

5.6 *flammable liquid* — a liquid having a flash point below 37.8°C (100°F).

5.7 *hazard* — a condition that is a prerequisite to a mishap.

5.8 *hazardous voltage* — unless otherwise defined by an appropriate international standard applicable to the equipment, voltages greater than 30 volts rms, 42.4 volts peak, 60 volts dc are defined in this document as hazardous voltage.

NOTE 6: The specified levels are based on normal conditions in a dry location environment.

5.9 *ignition energy* — sufficient energy to ignite a combustible material. The energy required depends on the form of the energy and the composition and form of the combustible material.

NOTE 7: The combustible material may be solid, liquid, or gas.

5.10 *likelihood* — the expected frequency with which a mishap will occur. Usually expressed as a rate (e.g., events per year, per product, per wafer processed).

5.11 *mishap* — an unplanned event or series of events that results in death, injury, occupational illness, damage to or loss of equipment or property, or environmental damage.

5.12 *noncombustible material* — a material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion,

1 National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269
2 Factory Mutual Research Corp., 1151 Boston-Providence Turnpike, Norwood, MA 02062
3 Underwriters Laboratory, 333 Pfingsten Rd, Northbrook, IL 60062

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or release flammable vapors when subjected to fire or heat. Typical noncombustible materials are metals, ceramics, and silica materials (e.g., glass and quartz).

5.13 *non-recycling deadman-type abort switch* — a type of abort switch that must be constantly held closed for the abort of the detection or suppression system. In addition, it does not restart or interrupt any time delay sequence for the detection or suppression system when it is activated.

5.14 *process chemicals* — solids, liquids, and gases used in the normal use of the equipment included in the scope of this document.

NOTE 8: Solids, liquids, and gases used in the maintenance procedures (e.g., isopropanol used as a cleaning agent) specified by the equipment supplier should be considered as well as those used in operation.

5.15 *pyrophoric material* — a chemical that will spontaneously ignite in air at or below a temperature of 54.4°C (130°F).

5.16 *residual risk* — that risk which remains after engineering, administrative, and work practice controls have been implemented.

5.17 *risk* — the expected losses from a mishap, expressed in terms of severity and likelihood.

5.18 *safe shutdown condition* — a condition in which all hazardous energy sources are removed and hazardous production materials are removed or contained, unless this results in additional hazardous conditions.

5.19 *semiconductor manufacturing process* — those manufacturing steps which are part of the creation of active or passive electrical devices on a semiconducting wafer, including the deposition of passivation layers after final metallization, but excluding testing and dicing.

5.20 *severity* — the extent of the worst credible loss from a mishap caused by a specific hazard.

5.21 *supervisory alarm* — an alarm indicating a supervisory condition.

5.22 *supervisory condition* — a condition in which action or maintenance is needed to restore or continue proper function.

5.23 *trouble alarm* — an alarm indicating a trouble condition.

5.24 *trouble condition* — a condition in which there is a fault in a system, subsystem or component that may interfere with proper function.

6 Fire Risk Assessment

6.1 *Overview*

6.1.1 This section provides criteria for evaluation of the risks associated with several types of fire hazards.

6.1.2 For each identified hazard described in Section 6, the evaluator should analyze the contributing, causal, and mitigating factors. The evaluator should also review any assessment of the material, component, or equipment as a whole by an accredited testing laboratory.

6.1.3 The risk assessment should include both normal operation and the consequence of reasonably foreseeable, single-point failures within the equipment. It should not include exposure to fire or external ignition sources not within the intended use environment.

6.1.4 Certifications by an accredited testing laboratory of materials, components, or the equipment as a whole may be used in the fire risk assessment. However, such certifications are valid only to the extent that the conditions of use for the certification correlate to the conditions of use for the equipment whose fire risk is being assessed.

NOTE 9: For example, a personal computer certified to IEC 60950 might be incorporated into equipment for use as a controller. The material flammability requirements of IEC 60950 may or may not be sufficient for this use of the personal computer, depending upon its exposure to oxidizers and external sources of ignition when incorporated into the equipment. Also, the levels of smoke tolerable in the environment for which a general industry standard was written may exceed those tolerable in semiconductor manufacturing cleanrooms. Furthermore, if the equipment is intended to be used in a potentially explosive atmosphere, the certification to IEC 60950 would not sufficiently control its risk of being a source of ignition.

6.1.5 The consequences and the probability of fire from each identified hazard should be assessed and rated, as described in SEMI S10. See Appendix 1 for the criteria used for the assignments of Severity, Likelihood and Risk in this document.

6.1.5.1 The assigned Severity and Likelihood and resulting Risk category should be recorded as part of the analysis.

6.1.5.2 For those hazards for which the Risk depends on the conditions of use or use environment, the equipment supplier should make and state appropriate assumptions. If the equipment supplier is unable to make appropriate assumptions as to the Likelihood because it depends predominantly on factors in the users' sole control (e.g., adherence to specified procedures), the supplier should state that and provide an estimate of the Severity.

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NOTE 10: The facilities requirements on which the risk assessment depends are to be specified by the equipment supplier.

6.1.6 For fire to occur, there must be a fuel, an oxidizer and a source of ignition. Elimination of any of these factors eliminates the risk of fire. Similarly, the Severity, Likelihood and Risk of a fire can be reduced by reducing one or more of these elements appropriately.

6.1.7 It is important to remember that there are often implicit oxidizers (e.g., room air) and sources of ignition (e.g., room temperature for a pyrophoric material).

6.1.8 The fire risk assessment should include the judgement of a qualified (as described in SEMI S7) party to determine the level of detail of the assessment. That party may group similar hazards for assessment and reporting.

NOTE 11: Such grouping could include, for example, all of the knobs and buttons of similar materials into one group, the heated surfaces into a second, and the several flammable liquids with similar properties into a third.

6.2 *Fuels*

6.2.1 Fuels include all those materials capable of reacting with an oxidizer in a fire. The risks of both the materials of which the equipment is constructed and the process chemicals used in it should be assessed.

6.2.2 *Materials of Construction*

6.2.2.1 The risk assessment should include all of the materials of construction, regardless of quantity or application.

NOTE 12: This includes small parts, such as knobs, buttons, electrical contactors, terminal strips, circuit boards, signal wire and power wiring as well as large components, modules (such as mini-environments) and subassemblies.

NOTE 13: Some of the smallest components can create a high risk, as in the potential for ignition by adiabatic compression of fluoropolymer seats in high pressure oxygen valves.

NOTE 14: The assessment can be simplified by grouping similar items together. Example 1: wiring that has the same type of insulation. Example 2: knobs, switches, handles and latches made from similar polymers. Identified groups should include their approximate total mass.

6.2.2.2 In assessing the risk, the evaluator should consider:

- the size of each component,
- the total quantity and distribution of similar components,
- the inherent properties of the material, such as ignitability, flame spread, heat of combustion, and byproducts (see Appendix 2 for guidance on evaluation of these properties),
- the exposure to oxidizers, and
- the exposure to ignition sources.

NOTE 15: The specification control of materials used in approved electrical components should also be considered. Approvals may allow for substitution of many materials with equivalent flammability ratings.

NOTE 16: The inherent properties of materials affect two types of risk within the equipment: flame spread risk and contamination risk (i.e., smoke damage from combustion byproducts). In the case of electrical and electronic components used in assemblies and equipment that are constructed and used in accordance with applicable standards (e.g., IEC 61010-1, IEC 60204-1), flame spread risk may be adequately controlled by the standard, and detailed assessment of the material properties of such components that affect flame spread may not be warranted. However, a significant contamination risk could still remain (e.g., a standard may allow a component mounted on a printed circuit board to fail and burn, as long as the burning remains local to the printed circuit board) and warrant a detailed assessment of related material properties of the components. The level of detail of the assessment may also be affected by the mitigation method chosen (see Section 7).

6.2.3 *Process Chemicals*

6.2.3.1 This portion of the risk assessment should include all of the process chemicals expected (based on the equipment supplier's recommended or baseline processes) to be used in the equipment. It should also include flammable and combustible wastes generated or collected within the equipment and fluids in the equipment which are required for its operation but which do not participate chemically in the process (e.g., vacuum pump oil).

6.2.3.2 In assessing the risk, the evaluator should consider:

- the quantity, concentration, state, temperature, and pressure of each chemical in each container,
- for those chemicals supplied automatically by the facility, the available flow, pressure, and total quantity,
- the aggregate supplies and distribution of similar chemicals,
- the inherent properties of the chemicals, such as flammable limits, flash point, autoignition temperature, heat of combustion, and the products of combustion and decomposition (see the Material Safety Data Sheets for guidance on evaluation of these properties),

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