SEMI S14-0309
SAFETY GUIDELINES FOR FIRE RISK ASSESSMENT AND MITIGATION FOR SEMICONDUCTOR MANUFACTURING EQUIPMENT

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NOTICE: Paragraphs entitled 'NOTE' are not an official part of this document and are not intended to modify or supersede the official Safety Guideline. These have been supplied by the Task Force to enhance usage of the Safety Guideline.

NOTICE: The intent of the task force that produced this Document is that conformance to the 'should' provisions of this guideline comprises conformance with this guideline.

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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 clean-rooms 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.

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

3 Limitations

3.1 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.

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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.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

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

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 and Risk Evaluation Process

4.2 *FM Global Document*[1]

4910 — Clean Room Materials Flammability Test Protocol

4.3 *NFPA Documents*[2]

NFPA 12 — Standard on Carbon Dioxide Fire Extinguishing Systems

NFPA 13 — Standard for the Installation of Sprinkler Systems

NFPA 72 — National Fire Alarm Code

NFPA 2001 — Standard on Clean Agent Fire Extinguishing Systems

4.4 *UL Documents*[3]

UL 94 — Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

UL 746A — Polymeric Materials – Short Term Property Evaluations

UL 746B — Polymeric Materials – Long Term Property Evaluations

UL 746C — Polymeric Materials – Use in Electrical Equipment Evaluations

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

[1] FM Global., 1301 Atwood Avenue, Johnston, RI 02919, USA. Telephone: +1.401.275.3000; Fax: +1.401.275.3029; http://www.fmglobal.com

[2] National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269, USA; Telephone: +1.617.770.3000, Fax: +1.617.770.0700, http://www.nfpa.org

[3] Underwriters Laboratory, 2600 N.W. Lake Road, Camas, WA 98607-8542, USA; Telephone: +1.877.854.3577, Fax: +1.360.817.6278, http://www.ul.com

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5 Terminology

5.1 *Definitions*

5.1.1 *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. [SEMI S2]

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

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

5.1.3.1 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.

5.1.4 *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 4: A list of criteria, guidelines and standards that may be used to evaluate the fire properties of materials is included in Appendix 2.

5.1.5 *downtime* — the time when the equipment is not in a condition, or is not available, to perform its intended function. It does not include any portion of non-scheduled time. [SEMI E10]

NOTE 5: Downtime may be considered according to the definition of SEMI E10, assuming committed availability of the parts in question.

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

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

5.1.8 *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.

5.1.9 *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.

5.1.10 *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).

5.1.11 *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.

5.1.12 *noncombustible material* — a material that, in the form in which it is used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat. Typical noncombustible materials are metals, ceramics, and silica materials (e.g., glass and quartz).

5.1.13 *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.

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

5.1.15 *residual risk* — risk remaining after engineering, administrative, and work practice controls have been implemented. [SEMI S10]

5.1.16 *risk* — the expected magnitude of losses from a hazard, expressed in terms of severity and likelihood. [SEMI S10]

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5.1.17 *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.

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

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 § 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 foresee-able, 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.

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.

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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 § 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, auto-ignition temperature, heat of combustion, and the products of combustion and decomposition (see the Material Safety Data Sheets for guidance on evaluation of these properties),
- the exposure to oxidizers, and
- the exposure to ignition sources.

NOTE 17: Chemicals with similar fire properties may be considered together for the purpose of this assessment.

6.3 *Sources of Ignition*

6.3.1 Sources of ignition can be broadly divided into those within the equipment and those external to it.

6.3.2 *Internal Sources*

6.3.2.1 Potential electrical ignition sources:

- devices or conditions that in normal operation can generate ignition energy (e.g., heaters, static electricity, lasers);

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- devices or conditions that in reasonably foreseeable assembly, use and/or wear conditions can generate ignition energy (e.g., power connectors, terminal strips);
- devices that in reasonably foreseeable single point failure modes can generate ignition energy (e.g., transformers, electronic components); and
- short circuits.

6.3.2.2 Potential chemical ignition sources:

- exothermic process chemical reactions,
- exothermic reactions from inadvertent mixing of process chemicals,
- exothermic reactions between process chemicals and materials of construction, and
- release of pyrophoric or air-reactive chemicals from processing or maintenance.

6.3.2.3 Sudden changes in process conditions:

- rapid (sometimes called 'adiabatic') compression of gas mixtures, and
- rapid increases in temperature.

6.3.2.4 Mechanical friction.

6.3.3 *External Sources*

6.3.3.1 External sources include expected and foreseen conditions of the equipment's use. As these are factors normally outside the control of the equipment supplier, their risks are difficult to assess. They are outside the scope of this Document.

6.4 *Oxidizers*

6.4.1 The most common oxidizer is air, which is present within and around most semiconductor manufacturing equipment. Unless specific measures are taken to exclude air (e.g., inert pressurizing of an electrical enclosure), it should be assumed to be available in infinite supply.

6.4.2 It is possible that some materials of construction will act as oxidizers or will yield oxidizers when subjected to heat.

6.4.3 Several common process chemicals (e.g., oxygen and hydrogen peroxide) are oxidizers. Their risks should be assessed in a manner similar to that described above for process chemicals that are fuels.

6.5 *Reporting*

6.5.1 Although these guidelines are intended for use throughout the design and development process, it is not the intent of these guidelines that the equipment supplier should make all of the information recorded during the development of the equipment available to others. The equipment supplier should document the fire risk assessment and mitigation in three forms: internal records, a final fire risk assessment report, and a summary report.

6.5.2 Relevant analyses, assessments, and design decisions should be documented in the equipment supplier's internal records. These records need not, however, be made available to other parties.

6.5.3 *Final Fire Risk Assessment Report*

6.5.3.1 This report should contain an itemized list of the residual risks identified in reviewing the final design, considering the risks described in the preceding subsections or otherwise known or foreseen by the evaluator. Only those risks meeting the criteria in Appendix 1 should be included. For each identified residual risk, the report should:

- explain the mechanism of loss or damage;
- identify aggravating or necessary contributing factors;
- identify the mitigating factors;

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- state the assigned Severity for each type of loss and present the rationale for its assignment. A 'type' is a column in Table A1-1 (e.g., 'Equipment Physical Damage');
- state the assigned Likelihood and present the rationale for its assignment; and
- state the resulting Risk category.

NOTE 18: Criteria for risks may be found in Appendix 1, ¶¶ A1-2.5 through A1-2.8.

6.5.3.2 This report should also describe the fire risk mitigation techniques included in the equipment design.

6.5.3.3 The final fire risk assessment report should be prepared or reviewed by a party qualified, as described in SEMI S7, to do such work.

NOTE 19: This party may be an employee of the equipment supplier or may be a third party.

6.5.3.4 When this guideline is being used as part of a SEMI S2 equipment evaluation, the manufacturer should make the final fire risk assessment report avail-able to the party performing the SEMI S2 evaluation.

6.5.3.5 The equipment supplier may make the final fire risk assessment report available to other parties.

6.5.4 *Summary Report*

6.5.4.1 The summary report should be prepared from the final fire risk assessment report and contain:

- a list of the residual fire risks and their ratings, and
- brief descriptions of the fire risk mitigation techniques included in the equipment.

6.5.4.2 The equipment supplier should provide the summary report to users of the equipment and may provide it to other parties.

7 Fire Risk Mitigation

7.1 *Overview*

7.1.1 This section describes several means of mitigating the risks of fire. It describes ways in which the equipment and its use can be designed to minimize the risks.

NOTE 20: The description of a mitigation technique in this section is not intended to imply that such technique should be used for each system. Therefore, the decision to include a particular mitigation technique should be based on the assessed risk.

NOTE 21: Fire detection and suppression are also means of mitigating fire risk. The criteria for fire detection and suppression systems are in SEMI S2.

7.1.2 In mitigating risks, the general hierarchy of elimination, engineering controls, administrative controls, warning and work practices should be followed. Following this hierarchy comprises using techniques which are highest in it if several techniques are equally applicable. Design and use constraints, as well as relative cost, however, may justify using techniques from generally less preferable categories. In any case, the residual risk should be assessed and reported.

7.2 *Fuels*

7.2.1 *Materials of Construction*

7.2.1.1 The lowest fire risk is posed by noncombustible materials of construction. Available noncombustible materials are not, however, suitable or desirable for all applications within semiconductor manufacturing equipment.

NOTE 22: The properties necessary to perform the intended function of system components and the properties necessary to satisfy component-level standards may also restrict the use of noncombustible materials.

7.2.1.2 When materials which are combustible are chosen, the fire risk may be mitigated by:

- selecting those materials with the least undesirable properties as described above; and
- minimizing the total mass and distribution of such materials.

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