Fire Risk Assessment and Mitigation for Semiconductor Process Equipment

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Outline

This presentation includes:

- Overview of fire risks
- SEMI S2-93A Fire Protection criteria
- SEMI S2-0200 Fire Protection criteria
- SEMI S14-0200 *Safety Guidelines for Fire Risk Assessment and Mitigation for Semiconductor Manufacturing Equipment*
- Summary
Overview of Fire Risks

Prerequisites for fire:

- Three elements of the “fire triangle”:
  - fuel
  - oxidizer
  - source of ignition

- All three must be:
  - in the same place
  - at the same time
Overview of Fire Risks

Risk is an estimation of the expected loss from a hazard. It is a function of:

- **Severity**
  - The foreseen degree of loss in a particular scenario
  - Expressed on a pre-defined scale

- **Likelihood**
  - The probability that the scenario will occur
  - Expressed as a percentage of the systems per unit time
SEMI S2-93A Fire Protection Criteria

- **Materials**
  - Use of combustible and smoke-generating materials “limited”
  - Separation of flammable and combustible materials from potential ignition sources
  - Combustible materials rated “less than UL 94V-0” limited to < 20% of surface area
  - Circuit boards “UL94V-1 rated or better”
SEMI S2-93A Fire Protection Criteria

- Detection and Suppression
  - Enclosures > 1.4 m$^3$ (50 ft$^3$) “evaluated” for detection systems
  - Detection systems listed or recognized
  - Equipment supplier to “consider” fire suppression.
  - Detection systems capable of interfacing with facility alarm systems
SEMI S2-0200 Fire Protection Criteria

- Risk assessment
  - In keeping with the S2 revision effort, risk is to be assessed and reported
  - Calls for risk assessment of the equipment and of the fire risk reduction features
  - Allows for optional fire risk reduction features to accommodate differing levels of risk acceptance

- Prescriptive components
  - Limited to those the supplier and user communities consider to be common to most equipment
  - Describe how some features, such as detection, are to be provided, but direct the inclusion of such features only if risk assessment finds them necessary.
SEMI S2-0200 Fire Protection Criteria

- Risk reduction
  - Materials of construction
    - noncombustible “wherever reasonable”
    - second choice is materials which do not propagate flame
    - selection based on minimizing fire risk by choice, using appropriate test methods, among the materials suitable for the process needs
    - optional flowchart for selection is included as an Appendix
    - hazards from materials of construction may be reduced, such as by
      - barriers separating combustible materials from sources of ignition
      - use of suppression systems
Risk reduction

- Process chemical hazards
  - consideration of substitution of nonflammable process chemical for flammable
  - hazards from process chemicals may be reduced, such as by
    - controlling mixing of chemicals which can react with each other
    - controlling chemical temperatures
SEMI S2-0200 Fire Protection Criteria

- Risk reduction
  - Engineering controls
    - interlocks prevent power and chemical flows
      - that could present unacceptable risk
      - when detection or suppression is inactive
    - control of smoke by exhausting it from the cleanroom
      - may be used when risk is presented by the spread of products of combustion
SEMI S2-0200 Fire Protection Criteria

- Risk reduction
  - Fire detection and suppression
    - included only if indicated by risk assessment
    - components suitable for use in the process equipment and certified by an accredited testing laboratory
    - installed in accordance with appropriate standards
    - capable of interfacing with facility systems
    - may be specified by equipment supplier but provided by equipment user
SEMl S2-0200 Fire Protection Criteria

- Risk reduction
  - Fire detection and suppression
    - shutdown equipment as quickly as safety considerations permit upon detection of fire
    - prevent additional use of equipment if detection or suppression system is not operating properly
SEMI S2-0200 Fire Protection Criteria

- Risk reduction
  - Fire detection and suppression
    - remain active
      - during maintenance
      - if equipment control system fails
      - when other hazardous energies are locked out
      - when EMO is activated
SEMI S2-0200 Fire Protection Criteria

- Risk reduction
  - Fire detection and suppression
    - Warnings and safe work practices for detection and suppression system to be provided
    - Maintenance and test procedures to be provided
    - Environmental effects of suppression systems to be documented
SEMI S14-0200: Safety Guidelines for Fire Risk Assessment and Mitigation

- Purpose
  - provide consideration for assessing and mitigating fire risks
  - to be used for both design and assessment of equipment
  - recommend traditional risk management hierarchy:
    - elimination
    - engineering controls
    - administrative controls
    - warnings
    - work practices
  - Result of applying this Safety Guideline is a report of residual fire risk
SEMI S14-0200

Scope

- process, measurement, test, and assembly equipment, used within fab cleanroom or its recirculating air stream
- applies to fire risks originating within the equipment that could lead to damage to the equipment, other equipment, products or the facility
Limitations

- no acceptance criteria for residual risk are established
- does not specify which mitigation methods to use or rate the relative merit of various methods
- apply to the protection of property, not of personnel
- applies to equipment when used as specified
- does not apply to equipment subjected to external fire
- not intended for use as regulations, which take precedence
Risk Assessment: Overview
- performed for each identified hazard
- includes analysis of contributing, causal and mitigating factors
- includes other reviews and certifications of components, but considers special needs because of cleanroom use
- considers dependence of risk on conditions of use
SEMI S14-0200

Risk Assessment: Fuels
- Materials of construction
  - all components, from knobs to equipment enclosure walls
    - may be grouped for assessment
  - assessment considers:
    - size
    - quantity and distribution of similar components
    - material properties
    - exposure to oxidizers
    - exposure to ignition sources
Risk Assessment: Fuels
- Process chemicals
  - Includes
    - all chemical for intended use (process and maintenance)
    - flammable and combustible waste
    - auxiliary fluids, such as vacuum pump oil
  - assessment considers:
    - state, quantity, concentration, temperature
    - available flows and pressures for externally-supplied chemicals
    - material properties
    - exposure to oxidizers
    - exposure to ignition sources
Risk Assessment: Oxidizers

- most common is air
  - should be assumed available, unless deliberately excluded
- some materials of construction
  - act as oxidizers or provide oxidizers when heated
- process chemicals
  - same considerations as described for process chemicals which are fuels
  - examples: oxygen, fluorine, hydrogen peroxide
Risk Assessment: Internal sources of ignition
- electrical ignition energy available
  - in normal operation (such as heaters, static electricity, lasers)
  - from use, wear, misassembly (such as connectors, power strips)
  - from single-point failure (such as transformers, short circuits)
Risk Assessment: Internal sources of ignition
- chemical (exothermic reactions)
  - process recipes
  - inadvertent mixing of process chemicals
  - between process chemicals and materials of construction
  - between released chemicals (such as pyrophoric gases or wastes) and air
Risk Assessment: Internal sources of ignition
  – sudden changes in process conditions
    • rapid compression of gas mixtures
    • rapid increases in temperature
  – mechanical friction
SEMI S14-0200

- Risk Assessment: Procedure for each hazard (step 1)
  - identify and describe:
    - hazard
    - mechanism
    - foreseen losses
  - identify aggravating, contributing and mitigating factors
  - assign a Severity for each foreseen loss
### Risk Assessment: Severity Groupings

<table>
<thead>
<tr>
<th>Severity Group</th>
<th>Equipment Physical Damage</th>
<th>Equipment Loss of Use</th>
<th>Facility Loss of Use</th>
<th>Environmental and Real Property Contamination</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Catastrophic</td>
<td>Loss of entire piece of equipment</td>
<td>One year</td>
<td>One week</td>
<td>Lasting facility or environmental impact</td>
</tr>
<tr>
<td>2) Severe</td>
<td>Loss of major subsystem</td>
<td>One month</td>
<td>One day</td>
<td>Temporary facility or environmental impact</td>
</tr>
<tr>
<td>3) Moderate</td>
<td>Loss of minor subsystem</td>
<td>One week</td>
<td>One shift</td>
<td>Limited to the equipment, but requiring more than routine cleanup</td>
</tr>
<tr>
<td>4) Minor</td>
<td>Non-serious equipment loss</td>
<td>One day</td>
<td>Less than one shift</td>
<td>Requiring routine cleanup but not external reporting</td>
</tr>
</tbody>
</table>
Risk Assessment: Procedure for each hazard (step 2)
- identify and describe factors that effect foreseen frequency
- assign a Likelihood for each foreseen mechanism and loss
## Risk Assessment: Likelihood Groupings

<table>
<thead>
<tr>
<th>Likelihood Group</th>
<th>Expected Frequency (% of systems per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) Frequent</td>
<td>More than 1%</td>
</tr>
<tr>
<td>B) Likely</td>
<td>More than 0.2%, but not more than 1%</td>
</tr>
<tr>
<td>C) Possible</td>
<td>More than 0.04%, but not more than 0.2%</td>
</tr>
<tr>
<td>D) Rare</td>
<td>More than 0.02%, but not more than 0.04%</td>
</tr>
<tr>
<td>E) Unlikely</td>
<td>Not more than 0.02%</td>
</tr>
</tbody>
</table>
SEMI S14-0200

Risk Assessment: Procedure for each hazard (step 3)
- identify Risk, based on Severity and Likelihood
- report:
  - Severity, Likelihood, and Risk for each mechanism and loss
  - rationale used to select Severity and Likelihood groupings
## Risk Assessment: Risk Categories

<table>
<thead>
<tr>
<th>Severity</th>
<th>Likelihood</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Critical</td>
<td>B</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>2</td>
<td>Critical</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>3</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Slight</td>
</tr>
</tbody>
</table>
Risk Mitigation: Overview

- Can be achieved by reducing risk of having a fire, or by reducing the loss from a fire, if it occurs

- Preference hierarchy
  - should be followed when equally-applicable options are available
  - may be over-ruled by design and use constraints

- Mitigation techniques should be chosen based on assessed risk
Risk Mitigation: Fuels

- Materials of construction
  - lowest risk obtained with noncombustible materials
  - noncombustible materials are not available for all uses
  - other materials should be
    - selected, using appropriate test methods, to minimize risk
    - minimized in mass and distribution
SEMIS14-0200

Risk Mitigation: Fuels and Oxidizers

- Process chemicals
  - may be possible to reduce risk by
    - changing chemicals or
    - reducing the quantities or pressures
  - risk may be reduced by limiting the factors described above in Risk Assessment
Risk Mitigation: Sources of ignition

- Risk may be reduced by:
  - limiting number of sources of ignition
  - limiting the energy of the sources
  - separating them from fuels (materials of construction and chemicals) by:
    - barriers
    - distance
Risk Mitigation: Exhaust, enclosures and barriers

- Exhaust may reduce risk by
  - reducing damage by removing combustion products
  - reducing concentrations of fuels and oxidizers

- Enclosures and barriers may reduce risk by
  - separating fuels, oxidizers and sources of ignition
  - limiting the spread of fire
  - limiting the spread of combustion and decomposition products
SEMIS14-0200

Risk Mitigation: Detection and suppression
- Criteria closely resemble those in SEMI S2-0200
Summary

- Overview of fire risks
- SEMI S2-93A
  - Few, but prescriptive criteria
- SEMI S2-0200
  - Incorporation of risk as basis for mitigation measures
  - Prescriptive criteria for most common measures
Summary

- SEMI S14-0200
  - Extensive discussion of risk factors
  - Prescribed risk assessment procedure and criteria
  - Discussion of risk mitigation techniques
    - reduce likelihood of a fire
    - reduce the loss if a fire occurs