# AT Equipment Environmental Characterization Guideline

Rev. 2.0

# 1. Introduction

## Section 1.1 Introduction/Expectations

The semiconductor industry believes in the highest level of environmental performance for its operations. The semiconductor industry, as an end user, has a responsibility to its employees and the community to minimize the environmental impact of its process and operations. To fulfill this responsibility the semiconductor industry has set environmental performance goals for its processes and operations. We require our equipment suppliers to assist us in achieving these goals. The design of the equipment should include documented efforts to minimize the amount of chemicals necessary for normal processes as well as maintenance activities. Every effort should be made to reduce the consumption of natural resources. It is Intel's expectation that equipment suppliers minimize chemical consumption, production of waste emissions, and utilities – and thereby reducing the overall environmental footprint of the equipment.

This document has been designed to provide guidance to the equipment and abatement suppliers on how to characterize the environmental performance of their semiconductor processes to effectively complete a mass balance of inputs and outputs to/from the tool. The characterization will include quantification of air and water emissions, as well as solid/chemical waste streams. The final report will include measurement on the centerline process or normal design operations of the tool, including baseline materials, if the end user's operation parameters (i.e., UPH, materials, etc) are not known to the supplier. If appropriate, information should be provided on a design of experiments (DOE) for variables that could affect the emissions quantities or characterizations. The following table gives a general guideline for what type of emissions information is required for each tool type.

**Table 1 – Tool Type and Emissions Characterization Requirements**

| Tool Type | Air Testing | Water/Waste Testing | Solid/Chemical Waste Analysis | Parts Clean/ PMs/Wipedowns |
|---|---|---|---|---|
| Wafer Mount/lam/de-lam | | | X | X |
| Wafer saw/grind/scribe | | X | X | X |
| Pick and place | X | | X | X |
| Material Dispense | X | | X | X |
| Cure/Reflow ovens | X | | X | X |
| Burn in | | | X | X |
| Testers | | | X | X |
| Handlers | | | X | X |
| Metrology | | | X | X |
| Rinse/deflux | X | X | X | X |
| Tape and Reel | | | X | X |
| Inspection | | | X | X |
| Paste Print | X | | X | X |
| Mark | X | | X | X |
| Ball Attach | | | X | X |

| | | | | |
|---|---|---|---|---|
| Bag Sealers | | | X | X |
| Laser Scribe | X | | X | X |

Suppliers for all tool types should complete the form sections per Table 2.

**Table 2 – Emissions Testing Data Report Requirements**

| Section | All Manufacturers | Input Analysis | Air Testing | Water/Wastewater Testing | Parts Clean/ Wipedowns | Chemical Solid Waste |
|---|---|---|---|---|---|---|
| 4.1 | X | | | | | |
| 4.2 | X | X | | | | |
| 4.3 | | X | X | | | |
| 4.4 | | X | | | X | |
| 4.5 | | X | | | X | |
| 4.6 | | X | | X | | |
| 4.7 | | X | | X | | |
| 4.8 | | X | | | | X |

For each process application that the supplier plans to offer for manufacturing, provide the following information:

1. Chemical/Material and Water Mass Balance

A chemical mass balance must be presented to show the composition and quantity of each chemical used in the supplier's equipment and the composition and quantity of each waste stream discharged to each exhaust, wastewater, separate chemical drain or solid/chemical waste stream. This mass balance should include water use and wastewater discharges, if applicable and called out above in Table 1.

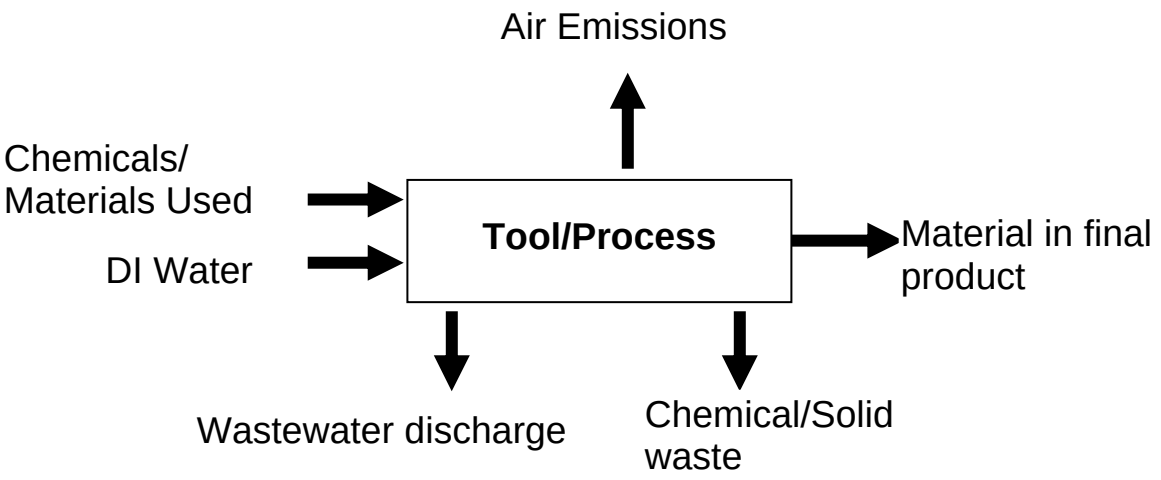
The mass balance shall:

- be on a per wafer, per unit or per time basis.
- include chemicals or materials used for maintenance and parts cleaning.
- be based on actual measurements, with analytical processes following standard, recognized methods (i.e., wastewater should be sampled and analyzed based on "Standard Methods for the Examination of Water and Wastewater")
- mass balance >90%

2. Air Emission Measurements

Emissions testing methods shall:

- be done by an approved method (i.e., Fourier Transform Infrared [FTIR] or Quadrupole Mass Spectrometer [QMS]).
- be reported on the Standard Format for Reporting Emissions Testing Results as outlined in Section 4
- include emissions from maintenance and parts cleaning operations in the emissions results.




**Section 1.2 Roles and Responsibilities of Suppliers for Selection Activity**

1. The supplier has a responsibility to assist the end user in achieving the customer's environmental emission goals.
2. Suppliers can perform the engineering analysis and emission measurements using approved in house analytical resources or the supplier can use a qualified third party.
3. It is suggested that the supplier contact a third party for establishing test methodologies based on the latest revision of methods specified in this document.
4. The supplier shall fill out the emissions report form completely.
5. The supplier shall provide a written engineering analysis and emission measurement report with supporting data.

**Section 1.3 Items to be Reviewed with Third Party by Equipment Supplier**

It is suggested that the following actions be included in your preparation for requesting quotes from potential third party consultants. Your preparation time in the process will help to control costs and schedule issues. You need to match your concerns to the capabilities of an outside third party resource. There are many third parties available; however, not all third parties have the same capabilities.

In an effort to determine the correct third party to meet your particular needs, the following are examples of questions that you may want to ask during the request for quotes, to ensure the best fit between you and your third party:

1. Can the third party provide a full emission analysis and emission report for each process application you plan to offer?
2. Does the third party have the internal expertise and analytical equipment required?
3. What are the strengths of the third party?
4. What are the weaknesses and how will the third party compensate?

5. What engineering resources can the third party provide to assist in determining solutions for any improvements to the equipment for reduction of environmental impact that may be identified to meet emission goals?
6. Will the third party review the equipment after completion of potential improvements and issue a final report?
7. What is their previous experience in conducting these types of characterization studies?

## 2. Emissions Characterization

### Section 2.1 Air Emission Characterization

The objective of the air emissions characterization requirement for equipment suppliers is to document the concentration of each constituent of the volatile portion or by-products of process chemicals/materials that may be used in conjunction with the normal operation of a tool. The most industry wide accepted methods for air emissions characterizations are Fourier Transform Infrared (FTIR) and Quadrupole Mass Spectrometry (QMS). Air emissions of interest include, but are not limited to those defined by the USEPA as Hazardous Air Polutants (HAPs), Volatile Organic Compounds (VOCs), Perfluorocarbons (PFCs) and those with Global Warming Potential (GWP), and should be quantified. More information can be found on the USEPA webpage at: http://www.epa.gov/

If any of the compounds listed below in Table 3 are expected or known to be present as an air emission during the normal operation of a tool, the supplier should refer to the International Sematech document, "Guidelines for Environmental Characterization of Semiconductor Equipment" for additional instructions on monitoring. The guideline can be found at the following link: http://www.sematech.org/docubase/abstracts/4197axfr.htm .

**Table 3 – List of Compounds Requiring Additional Monitoring Requirements**

$CH_3COCH_3$ (Acetone)
$CH_3OH$ (Methanol)
$C_2H_5OH$ (Ethanol)
$(CH_3)_2CHOH$ (Isopropanol)
$CH_3O(CH_2)_3OOCCH_3$ (PGMEA)
$C_2H_5OOCCC(OH)CH_3$ (Ethyl lactate)
$C_4H_6ON(CH_3)$ (NMP)
$C_4H_8SO_2$ (Sulfolane)
$CH_3(CO)C_5H_{11}$ (2-Heptanone)

### Section 2.2 Chemical/Wastewater Characterization

The objective of the chemical/wastewater characterization section is to provide a mass balance of all chemicals and water going into, and coming out of the tool. The table below should be used to satisfy the minimum requirements for chemical/wastewater characterization. This should be used as a guideline only, and if other constituents are expected to be present, a third party may be required to develop an effective

sampling plan. All analysis methods listed are referenced from "Standard Methods for the Examination of Water and Wastewater". Data should be collected while the tool is processing in a steady state mode.

**Table 4 – Minimum Wastewater Characterization Parameters**

| **Parameter** | **Standard Method of Analysis or EPA Equivalent Method** |
|---|---|
| pH | 4500-H+ |
| BOD (biological oxygen demand) | 5210B |
| COD (chemical oxygen demand) | 5220C |
| TSS (total suspended solids) | 2540D |
| Pb (total lead) | 3111B or C; 3113B; 3120 B |
| Cu (total copper) | 3111B or C; 3113B; 3120 B |
| Cr (total chromium) | 3111B or C; 3113B; 3120 B |
| Cd (total cadmium) | 3111B or C; 3113B; 3120 B |
| Surfactants (MBAS) | 5540C |
| P (total phosphorus) | 4500 |
| N (total nitrogen) | 4500 |
| Oil & grease | 5520B |

## 3. Emissions Report Format

### Section 3.1 General Information

This section outlines the instructions for completing the emissions forms found in Section 4 of this document. Please refer to Tables 1 and 2 to determine which sections of the form should be filled out. Section 4.1 is a requirement for all tools. Information to be included is general information about the tool and supplier. A detailed description of the tool, its process flow and a list of all the chemicals/materials associated with the normal process of the tool, including those used for PMs and cleaning, are to be provided.

### Section 3.2 Chemical/Material Information

The baseline equipment supplier's process recipe should be given. It must include flows, times, RF power, plasma pressure and spin speed. All sub steps to the process should be included. For example, some wafer saw processes have a spindle cool flow as well as a wafer rinse flow and a wafer cut water flow. The process parameters (flows, times, etc.) listed previously should be determined for each of the substeps of the overall process. If the end user's operation parameters (i.e., UPH, materials, etc) are not known to the supplier, the final report will include measurements on the centerline process or normal design operations of the tool, using baseline materials. If appropriate, information should be provided on a design of experiments (DOE) for variables that could affect the emissions quantities or characterizations.

**Section 3.3 Air Emissions Information**

The purpose of the following section is to provide guidance in correctly completing the air emissions form requirement for process tools. This document applies to all process tools that have an exhausted air stream from the process tool. Data in this section should follow the general information on emissions characterization outlined in Section 2.1.

Section 4.3 of the report will include :

1. The specific methodology used to determine the emissions
- who performed testing (in house vs. contractor), provide contact number for technical questions.

2. Instrumentation Parameters
- mass or wavenumber range, detection limits of instrumentation for each of the analyte compounds
- indicate model name and type
- sampling conditions for calibration and wafer/unit monitoring (source pressure, electron energy, sampling frequency, detection method and settings (faraday or multiplier), etc.)

3. Purge Pump Rate??

4. Calibration curves of signal vs. analyte concentration must be provided for each compound. A sample calibration curve is shown in Figure 3.1.
- slope (with error), y intercept and correlation coefficients, error not to exceed 5%
- Calibration curve of at least one point per factor of 10 and no less than 5 points

5. The mass balance of process chemicals/materials performed on a steady-state process
- chemicals/materials quantities in and out of the tool
- the volatile compound(s) associated with the mass balance
- the concentrations of the compounds

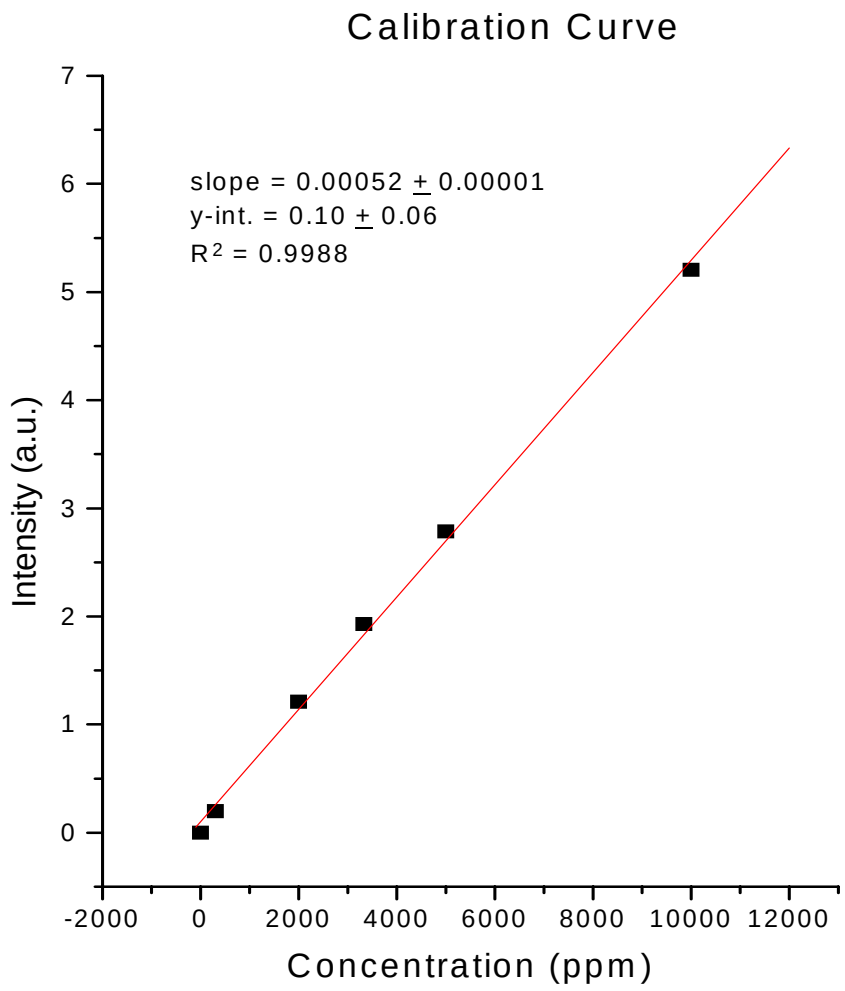



Figure 3.1 Sample figure for calibration curves.

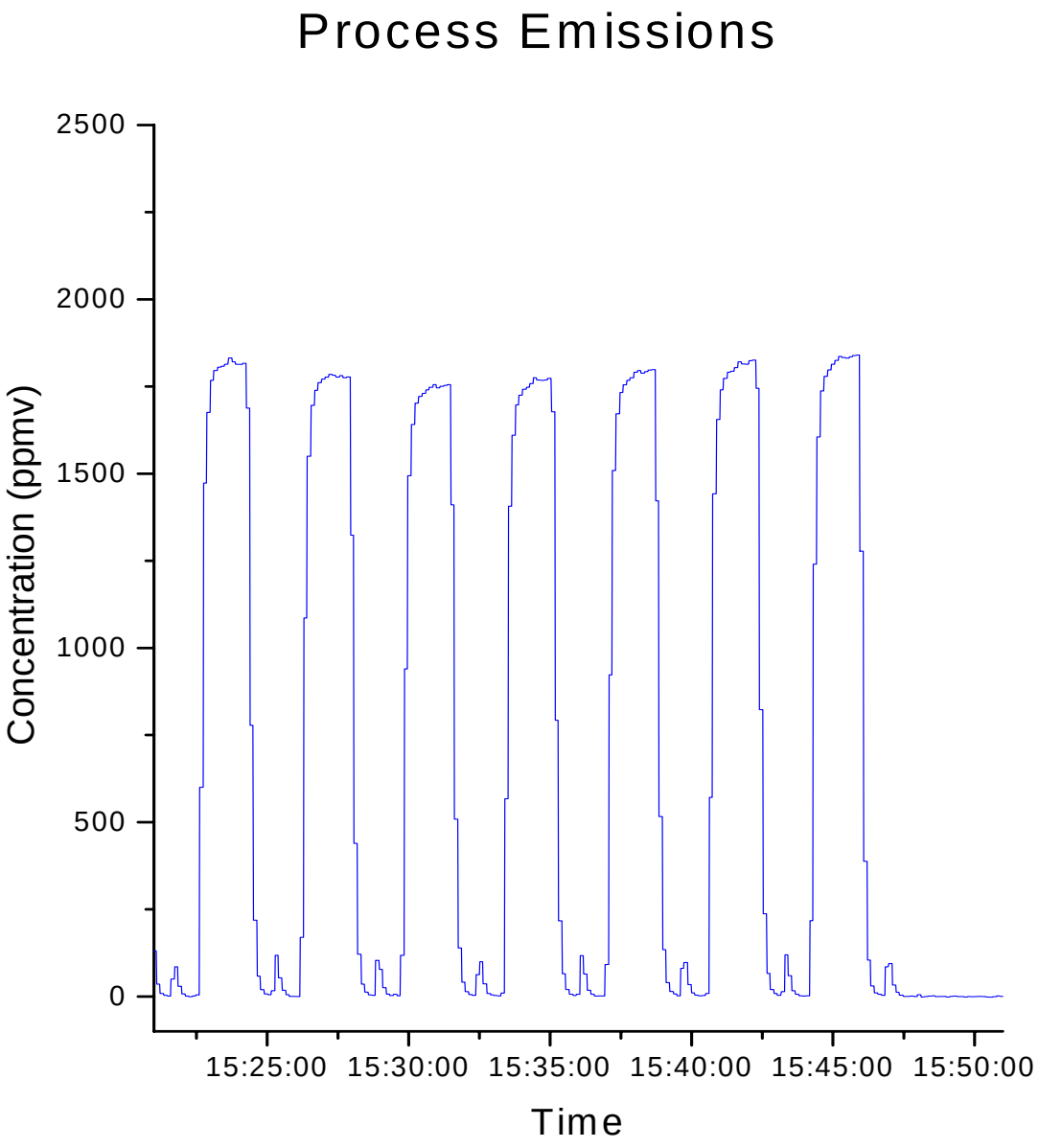



Figure 3.2 Example of Process Emission Plots

**Section 3.4 Preventive Maintenance Procedures (PMs)**

This section of the form is designed to provide information concerning the specific preventive maintenance procedures that are required for a given process/process tool.

Description of Procedure: A brief description of each preventive maintenance procedure must be provided. For example, a wet clean is an example of a procedure used during a PM. Other procedures which are routinely conducted during PMs that use chemicals must also be included in this section. Am example might be flux spray system that is routinely flushed with DI water to clear the lines and nozzle of residual flux.

Frequency of Procedure: This indicates how often the specific procedure is conducted on a per wafer, per unit or per time basis.

Method: This details how the procedure is conducted. Examples are : by wiping the chamber clean with a saturated wipe to clean the outside of equipment, using NMP solvent wash, using swabs with IPA to clean a nozzle.

Chemical Used: This details exactly which chemicals are used by the specific PM procedure and its concentration (e.g. 10% or 100%). Example: 100% Isopropanol (IPA)

Chemical (Vol./Procedure): This details how much of each chemical is used in the procedure on a per procedure basis. Example : 100 mls of IPA

Water (Vol./Procedure): The amount of water used on a per procedure basis must be indicated. Example: 5 gallons of UPW / procedure

**Section 3.5 Parts Clean**

Note: Even if the parts clean is outsourced, it must still be included.

This section of the form is designed to provide the details of the parts clean procedures that are required for a given process/process tool. Since it is assumed that usage equals emissions only usage data will be required for this section.

Frequency of Parts Clean: This indicates how often the parts clean is conducted on a per wafer, per unit or per time basis.

Cleaning Method: This details how the parts clean is carried out. Examples are: by bead blasting for 10 minutes, by etching in a 50 : 50 HF : water bath for 10 minutes, scraping or chemical solution for removal of materials, etc.

Chemical Used: This details exactly which chemicals are used in the parts clean process. Example: Acetone.

Chemical (Vol./Clean): This details how much of each chemical is used in the procedure on a per procedure basis. Example: 50 ml of HF/clean.

Water (Vol./Clean): The amount of water used on a per clean basis must be indicated. Example: 5 gallons of UPW / clean

**Section 3.6 Emissions From Process Tools Using "Open" Tanks/Baths**

There are additional testing concerns for conducting the emissions characterization of process tools which contain open bath/tanks, including those where "dragout" of a chemical is possible. Tools with IPA dryers also have additional testing requirements. In the event that the tool has an open bath or an IPA dryer process, supplier should refer to the International Sematech document, "Guidelines for Environmental Characterization of Semiconductor Equipment" for additional instructions on monitoring. The guideline can be found at the following link: http://www.sematech.org/docubase/abstracts/4197axfr.htm .

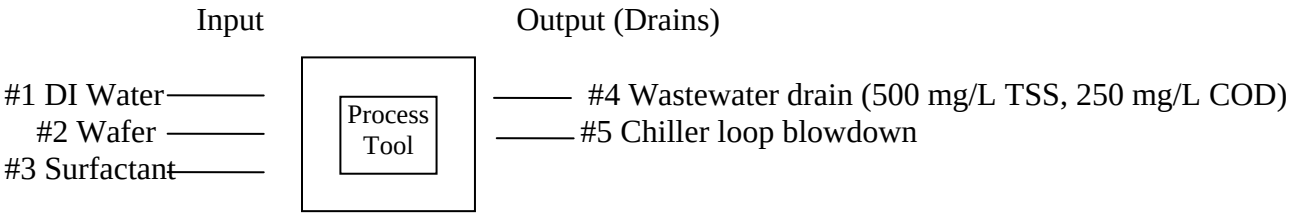
**Section 3.7 Chemical/Water Mass Balance**

The purpose of the following sections is to provide guidance in correctly completing the chemical usage and wastewater emissions form in order to fulfill the wastewater emissions requirement for process tool selection. This document applies to all process tools which have a drain in which liquid chemicals (i.e. pure or combined with water) or wastewater are emitted from the process tool, or per Table 1 of this document. Data in this section should, at a minimum, include data on the parameters outlined in Table 4.

**Section 3.8 Connection Hookup Diagram**

For Section 4.6 of the form, the equipment supplier should provide a detailed block diagram which clearly shows all of the points of connection to the process tool (both input and output liquid chemicals, water and wastewater). The drains should be labeled by type (i.e. solvent drain, acid drain, wastewater drain, etc.). Each connection should be numbered and the identity and concentrations of the primary constituents of the outputs (drains) should be included.

Example: A process tool with 5 connection points (3 inputs and 2 outputs/drains).




**Section 3.9 Chemical/Water Connections and Discharges**

For section 4.7 of the form, more specific information is required for each point of connection (whether it is an input chemical/water or an output chemical /wastewater/water).

The volume associated with each connection point must be included. If the chemical/water flows through the tool then the volume should be quantified in gallons per minute. For the constant flow rates a high flow rate and low flow rate along with an associated time per wafer, per unit or per time for each of the flows is required. If the chemical/water used is in the form of a static bath, then the volume should be expressed in gallons and the dump frequency included. If the connection point is a drain, then the outlet

flow rate of the chemicals/wastewater should be included. If input or output flows are not process related, but are continuous flows (i.e., spindle cool, chiller blowdown), those flowrates should be included. If the tool has more than one water use, a flowrate for each use should be identified (i.e., spindle cool, rinse, backgrind). Finally, the primary constituents should be identified and quantified for each of the output connection points (drains). All concentrations should be the average of at least 5 cycles. Table 4 provides the minimum requirements for characterization, and national standard testing methods (such as US EPA regulations) or "Standard Methods for the Examination of Water and Wastewater" should be used for the testing procedures.

**Section 3.10 Chemical/Solid Waste Generated during Wafer/Unit Processing and PMs**

For section 4.8 of the form, the equipment supplier needs to provide information concerning the amount of solids that are emitted from the process tool. The equipment supplier must provide the identification of any solid material that is emitted from the process tool and the quantity of solid emissions in lbs/wafer, lbs/unit, or lbs/time from the tool during normal operation or during PMs. This analysis of wastestreams may include, but is not limited to epoxy/paste/flux tubes, batteries, used oil, light bulbs, filters, tape/reels, scrap tape/laminate, etc. Information should include the wastestream, the process that produces the stream and the quantity of the wastestream in lbs or grams per wafer, per unit or per time.

## 4. Standard Formats for Reporting Emissions Testing Results

This section contains the emission forms which are to be completely filled out by the equipment supplier.

| **4.1 General Information** To be completed for all tools | | |
|---|---|---|
| Equipment Name/Company | | |
| Function of Process Tool | | |
| Run Rate (wafers/hour, units/hour) | | |
| Number of Wafers/Units Tested | | |
| Process Description | | |
| **4.2 Chemical/Material Information** To be completed for all tools | | |
| **Input Analysis:** Describe the actions taken during tool design to reduce the amount or hazardous properties of chemical/material required for this tool. | | |
| **Chemicals/Materials Used **** Including water (DI or other) and all input materials | **Quantity** (e.g. lbs/wafer, gallons/unit, grams/unit) | **Purpose** (e.g. PM, process, input) |
| 1) | | |
| 2) | | |
| 3) | | |
| 4) | | |

** Please review the following URL to ensure that no banned materials or chemicals are being used in this process: http://supplier.intel.com/ehs/Intel_Banned_Materials_Spec_Rev4.doc

| **Section 4.3 Air Emissions Information** | |
|---|---|
| Analytical Methodology (FRIT, QMS) | |
| Technical Contact | |
| Instrumentation Used (make/model) | |
| Instrumentation Parameters (wavelength, settings, etc) | |
| Purge Pump Rate | |

**Input Analysis:** Describe what actions were taken to reduce the environmental impact due to air emissions from this tool.

| **Chemical/Material In** (g/unit, lbs/wafer, etc) | **Chemical/Material Out** (g/unit, lbs/wafer, etc) | **Emissions Compounds Measured** | **Concentration** (ppm, ppb) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

| **Section 4.4. Preventive Maintenance (PMs)** | |
|---|---|
| Description of Procedure | |
| Frequency of Procedure | |
| Method Details | |
| Chemical Used | |
| Chemical Quantity/Procedure | |
| Water Quantity/Procedure | |
| Other information | |

**Input Analysis:** Describe what actions were taken to reduce the environmental impact due to PMs from this tool.

| **Section 4.5. Parts Cleans** Include usage even if outsourcing of cleaning is suggested | |
|---|---|
| Description of Procedure | |
| Frequency of Procedure | |
| Method Details | |
| Chemical Used | |
| Chemical Quantity/Procedure | |
| Water Quantity/Procedure | |
| Other information | |

**Input Analysis:** Describe what actions were taken to reduce the environmental impact due to Parts Clean from this tool.

## Chemical/Water Mass Balance Section

**Section 4.6 Connection Hookup Diagram** attach a schematic per the example in Section 3.8

### Section 4.7 Chemical/Water Connections and Discharges

**Input Analysis:** Describe what actions were taken to reduce the environmental impact due to wastewater from this tool.

| **Connection #** | **Volume/flow**(gpm) | **Constituent** | **Concentration** (mg/L) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
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### Section 4.8 Chemical/Solid Waste Generated during Processing and PMs

**Input Analysis:** Describe what actions were taken to reduce the environmental impact due to chemical/solid waste generated from this tool.

| **Waste stream** | **Process** | **Quantity** (lbs/wafer, lbs/unit, lbs/time) |
|---|---|---|
| | | |
| | | |
| | | |