300mm Prime Guidelines

Phase 2
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JEITA-JSIA

Japan Electronics and Information Technology Industry Association-Japan Semiconductor Association

300mm Prime Task Force

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1. Next Generation Fab Image Intended by J300P Guidelines

1.1. Introduction

This guideline booklet has been developed by 300mm Prime Task Force affiliated with JEITA-JSIA (Japan Electronics Information Technology Association Japan-Japan Semiconductor Industry Association) Technology Committee, hereafter *J300P Task Force* since April 2006. The area of the guideline requirements is limited to production equipment and related peripheral capabilities per the agreement made among the JEITA-JSIA member companies.

This set of guidelines is expansion of the existing global guidelines (*GJG300: Global Joint Guidance for 300mm Semiconductor Factory CIM and EEC: Equipment Engineering Capabilities Guidelines*) to capture the requirements in the next generation semiconductor fabs as reduction in production cycle time, more stable and elaborate process outcome controllability, and, reinforced productivity in the production equipment. J300P Task Force reviewed the existing guidelines of both GJG300 and EEC. J300Ptask Force found they are *all* reusable except for new additional requirements that are collected in this booklet.

Phase 1 guidelines focus on wafer point of view visualization of factory and equipment activities and equipment quality, and phase 2 guidelines focus on equipment controllability, and phase 3 guidelines are planned to focus on inspection and metrology equipment and process quality control.

1.2. Background

First generation 300mm factories have been designed for thorough factory automation and built worldwide basis. There are following problems in terms of productivity and a paradigm shift in the manufacturing methodology now being sought.

(1) Wafer-level process outcome control capability in response to process node advancement

(2) Productivity and cycle time improvement in response to rapidly changing business requirement

Figure 1 shows the image of above mentioned paradigm shift in semiconductor factory and its manufacturing methodology. This figure was created by STRJ and presented in 2005 winter ITRS meeting.

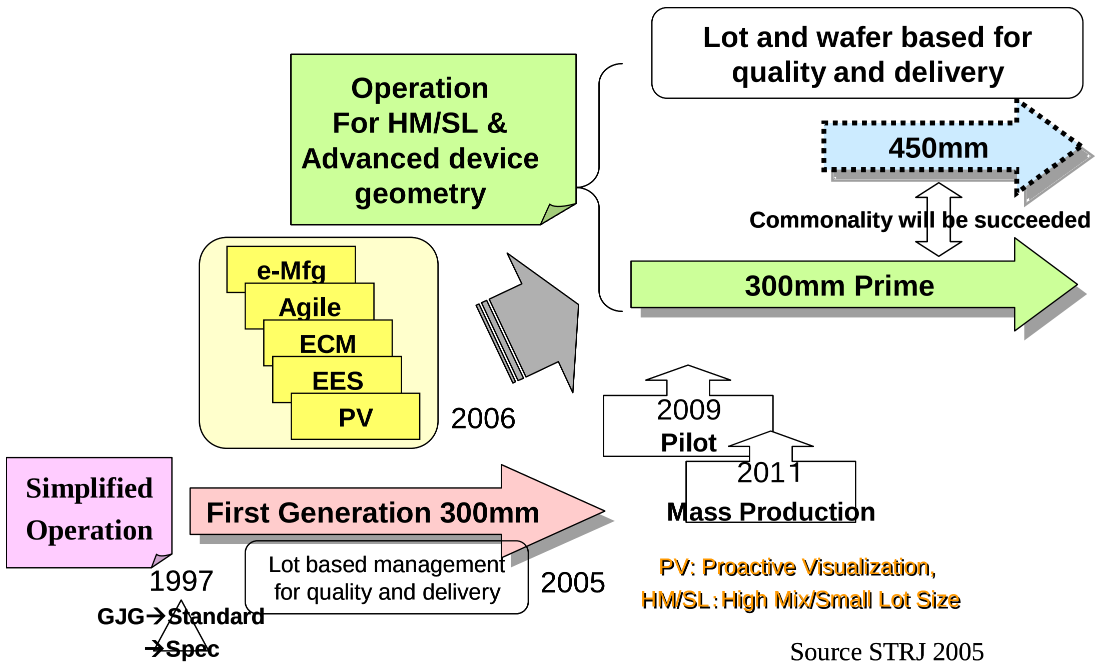

Figure 1: **Paradigm shift for the next generation semiconductor factory**

STRJ disclosed following manufacturing concepts in the preceding past 6 years to this guideline development; *e-Manufacturing, Agile-Manufacturing, Engineering Chain management, Equipment Engineering System, Proactive Visualization, Hierarchical Strategic Quality Assurance*. J300P Task Force formulated requirements as guidelines out of these manufacturing concepts with a focus on productivity, cycle time improvement, and, waste reduction.

1.3. Implementation Timings

Followings are implementation timings of the capabilities required in this guideline.

2008
Completion of equipment engineering data contents and data provision readiness that are asked in the base guidelines
Standardization of structured information of wafer's attributes and status
2009
Implementation of wafer traceability information from wafer point of view
Completion of standardization for equipment capability and relevant data models
Standardization of information definition for Dandori visualization
Implementation of graceful shut down of equipment that are asked in the individual wafer equipment control guidelines

Standardization of wafer management information at the interface between production equipment and factory for wafer

2010
Standardization and implementation of those wafer-level control capabilities required in sections 4 through 6.

2. Base Guidelines

Manufacturing management and control in wafer point of view

Wafer processing operations are graphically represented in Figure 2. A lot has been defined as a carrier containing 25 wafers and most of the production information has been defined based on this lot definition, and manufacturing is controlled and executed on this lot basis and the relevant information is gathered as well.

For the further improvement of the cycle time and productivity it will become important to utilize individual wafer's movement information that describe all experienced states in the course of fabrication at individual wafers internal and external to the equipment together with equipment operation log data. The scope of the base guidelines is that equipment productivity and equipment process control activities are to be analyzed at individual wafer-level so as to visualize individual wafer activities as well as productivity losses that have not been explored in the past in a comprehensive manner.

Phase 1 base guidelines present the requirements for factory activity visualization from the viewpoint of individual wafers and from the other conventional viewpoints as well such as factory resource view. Phase 2 base guidelines present the requirements for factory control from the viewpoint of individual wafers and from the other viewpoints such as equipment's *Dandori* control and equipment capability performance's chronicle drift compensation. The viewpoint of individual wafers requires structured information of wafer's attributes and status. This structured information needs to be standardized urgently. GL requires equipment to have wafer-level traceability based on this structured information as well.

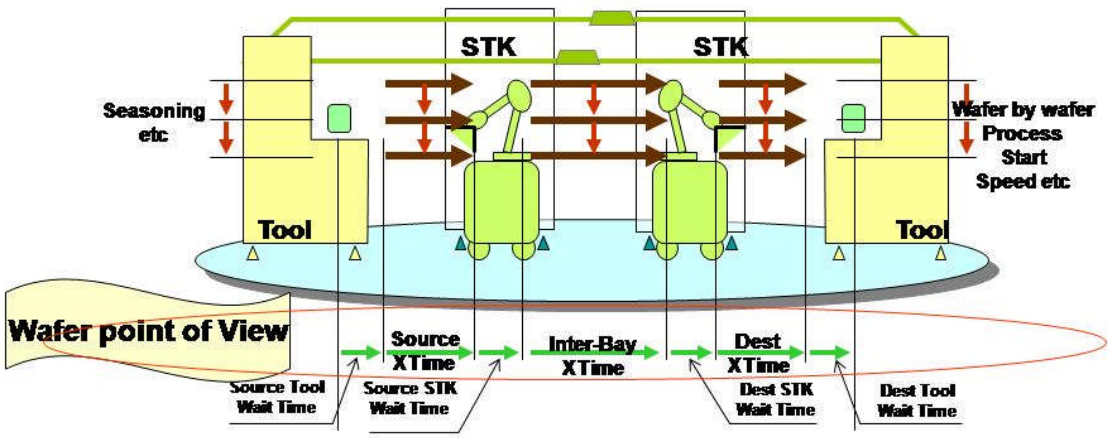

Figure 2: Cycle time visualization concept from wafer point of view

2.1. Manufacturing management and control in wafer point of view

Manufacturing management and control information shall be designed to allow elaborated wafer view utilization both in the factory and equipment systems.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
For the consistent improvement both in the cycle time and productivity it will become important to utilize factory information comprising of individual wafer's movement information that describe all experienced states in the course of fabrication internal and external to the equipment in conjunction with hierarchically structured relevant equipment activity log data. Wafer view factory information such as cycle time and waiting time information has been defined by individual device makers. The equipment activity information from the wafer viewpoint such as wafer movement upon load port transfer and equipment internal transfer events are provided by equipment suppliers in their specific manner. Wafer view information utilization will play an even more important role in the context of more complex and finer geometry fabrication.

Standards:
1. Wafer view cycle time related data such as individual wafers' waiting time, process time need clear definitions. Wafer view cycle time related data are to be defined to have a hierarchical structure in the standard.
2. The wafer-level traceability data shall be defined to have finer granularity in comparison to the lot-based traceability data. Particularly event data upon equipment's state changes shall be defined with high granularity for standardization.
Examples of data definitions that require standardization:

- Time duration of equipment internal fabrication or fabrication related operations from the viewpoint of individual wafers
- Graphical representation methods of equipment internal paralleled operations on multiple wafers,
- Discrete waiting time segments for individual wafer that comprise overhead time of individual wafers (known as B values):
    - Across the factory-equipment boundary;
        - Time of "paper work" of wafer carrier acceptance
        - Physical transfer time and some wait time
    - External to equipment;
        - Wait time for a carrier to be transported
        - Wait time in a queue
- Internal to equipment;

Time segments that cannot be hidden by parallelism of equipment internal processes that add up to the total lot cycle time

Production time discontinuity between consecutive 2 lots with different recipes

Time needed for batch formation

Cleaning and seasoning time, time used for particle check

Wait to time for manual operation, wait time for quality judgment, etc.

Wafer traceability information element examples:

Process sequences log data for individual wafers, Wafer rotation at relevant wafer positions, equipment group, equipment, equipment modules that individual wafers went through, carriers in which that wafer was contained

Examples of event data that support above mentioned wafer view data utilization;

Event of equipment status changes, its contents, and, event data definition in terms of engineering specifications and structural definition that contains relevant context information.

Remarks:

None

2.2. Production equipment quality assurance across business boundary

Production equipment quality shall be visualized, traced, and maintained across the equipment supplier-device maker business boundary.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers and device makers

Background and Purposes:
Production equipment quality is built into the equipment in the manufacturing process. This equipment quality will be succeeded and used in device maker's production line. It is important that quality maintenance and improvement activities at the equipment supplier and those at the device maker are mutually interrelated so as to improve the quality and efficiency of equipment engineering operations at both parties.

Standards:
Standard requirements will be described in the dependent lower level guidelines. For the implementation of this guideline following standardization efforts are required in plural industry domains.

Consortia campaign:

Business model study of Enhanced Equipment Quality Assurance
For EEQA see *http://jeita-smtc.elisasp.net/*

Implementation encouragement by consortia: Following publications
Establishment of EEQA's technical procedure as a common knowledge
Format of EEQA contents sheet
EEQA contents standardization of well-known equipment capabilities
Standardization of EEQA equipment engineering data and data specifications
EEQA equipment engineering data reutilization

Remarks:

Business model study as an industry is required for implementation of this guideline. Industry organizations from both equipment suppliers and device makers should conduct mutual and open investigation. For effective and proactive visualization of equipment quality each party should prepare to propose the equipment quality visualization contents. Device makers' active support of equipment suppliers' reutilizing the EEQA data for the further equipment quality improvement should become a common practice.

2.3. Hierarchical Assurance of equipment's process execution performance

Equipment's process execution performance quality (such as low failure rate, short equipment state validation time, low process outcome quality fluctuation, reduced machine-to-machine or chamber-to-chamber difference, shall be assured in accordance to equipment's hierarchical logical structure model. This quality validation shall be performed prior to equipment's acceptance to the production line by the equipment supplier. This quality assurance should be performed at needed frequency after the acceptance. The EEQA data shall be able to be shared between the equipment supplier and the device maker.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers, device makers, and third parties

Background and purposes:
Selected equipment engineering data sharing is required between the equipment supplier and the device maker for sufficient information support to maintain the equipment at the specified performance. Data selection shall be decided by collaboration between the equipment maker and the device maker.

Standard:
Hierarchical equipment logical structure (equipment level capability layer, equipment module level capability layer, part level capability layer) should be standardized.

Remarks:
Equipment reliability improvement is important to semiconductor manufacturing where inherent feature shrinkage continues. Scientific approach to the more stable equipment performance is eagerly expected with hierarchical quality traceability being in place from low component level to the whole equipment level.

3. Equipment Engineering Data/Model Definition

Proactive visualization of production equipment quality

3.1. Proactive visualization of production equipment quality

Production equipment quality shall be visualized with sharable healthiness and productivity evaluation methods and evidence data, and that visualized information shall be able to be reutilized.

Who to implement this guideline: equipment suppliers and device makers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes
Production equipment is the most important factory resource and its quality influences semiconductor product quality, cost, delivery time. Therefore the equipment quality validation at the time of acceptance to the production line and the equipment quality maintenance and tracking are very important equipment engineering operations. They need to be consequentially reinforced with scientific equipment engineering data.

Standard:

Equipment quality validation procedure shall be standardized.
Equipment engineering data for equipment quality description and evidence shall be standardized.

Remarks:

3.2. Reinforcement of production equipment quality assurance

Production equipment quality visualization, assurance, validation, and, trace shall be reinforced with using steadily available equipment engineering data from the production equipment.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
Currently available on-line equipment data is not utilized in a positive manner for production equipment quality assurance. Equipment capabilities shall be tuned, validated for performance with using steadily available equipment engineering data for the purpose of enhancing equipment quality assurance. Production equipment performance visualization and maintenance should use this steadily available equipment engineering data so as to succeed the initial equipment performance validation by using the same data.

Standard:
None

Remarks;
See guideline 2.6 for production equipment quality reinforcement.

3.3. Focus on equipment capabilities' visualization

Visualization of individual equipment capabilities and equipment control capability shall be prioritized in conducting production equipment quality validation, trace, and maintenance operations.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
An process tool is, for example, consist of process generation means such as reaction condition generation (pressure and reactant concentrations, etc.), wafer temperature adjustment means, wafer transportation means, and such. It is a basic and very first step to examine if individual equipment capabilities are functioning in accordance to their specifications or to what design intended.

Standard:
Validation procedures and the relevant data shall be standardized at least for the principal equipment capabilities.

Remarks;
There are several well-known equipment capabilities in production equipment. These capability performances shall be expressed as logical capability components and to be validated for their performances per these logical definitions. Accumulation of these logical components should validate the whole equipment performance so that that equipment quality is described.
Examples of equipment capability performance focus;
(1) Famous capabilities with well-known high trouble potential such as mass flow controllers, automatic pressure controllers …
(2) Machine-to-machine and/or chamber-to-chamber difference
(3) Repeatability of in-equipment process execution sequence

3.4. *Critical values provision of equipment performance healthiness determination*

Equipment supplier shall provide both sets of critical value sets to determine the healthiness of equipment capability performances and/or behaviors for the initial validation at the time of production line acceptance and for the continuous operation in production.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Equipment suppliers and device makers

Back ground/purposes:

Currently the critical values to determine the healthiness of an equipment capability performance for the initial validation at the time of production line acceptance and the critical value for the continuous operation in production that is the expectation of the performance stability are not well distinguished, and, hence, equipment suppliers have very often no such pairing design values. This ends up with poor traceability of equipment quality, and examination of particular equipment capability's healthiness is difficult without the provision of critical values for performance stability.
It is expected that the equipment supplier is most knowledgeable about the healthiness definition or designed criteria. Device maker engineers are also knowledgeable enough to set reasonable critical values for healthiness determination from his/her experiences, but not necessarily know all the equipment capabilities and because of their large number it is impossible to cover wide good portion of the capabilities.

Standard:

Behavior models and healthy operation models of principal equipment capabilities shall be standardized.

Remarks:

Equipment supplies are expected to continuously collect field data and proactive equipment quality visualization data to accumulate knowledge so as to elaborate visualization contents such as equipment capability healthiness determination criteria. Equipment suppliers are expected to improve their traceability capability with statistical analysis of equipment quality proactive visualization data from a large number of shipped tools, a large number of process chambers, or large number of individual logical equipment capability components

3.5. Collaboration between device makers and equipment suppliers

Device makers and equipment suppliers are to investigate and improve the contents of proactive equipment quality visualization collaboratively.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
Device makers are expected to propose the better contents of proactive equipment quality visualization from their experiences in running the production tool in mass production environment. The equipment quality data obtained for equipment capability validation at the time of production equipment acceptance to the production line shall be used by the equipment suppliers for improvement of equipment quality and services.

Standard:
Typical proactive equipment quality visualization shall be standardized.
Typical measurement methods of productivity and equipment capability performances shall be standardized including important trigger data.
Visualization items of productivity and equipment capability performances shall be distinctly sorted from the viewpoints of factory operation, production equipment, and, product wafers.

Remarks: none

3.6. Improved efficiency in equipment engineering data collection and data utilization

Equipment engineering data collection and data utilization shall be systemized with being embedded in the current workflows.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
If data gathering and analysis take too long for equipment quality improvement and maintenance, equipment quality visualization with enough coverage and depth cannot be achieved. The data gathering shall be done on-line as much as possible. Furthermore the necessary data extraction, information abstraction, data sorting and accumulation per individual equipment capabilities, statistical determination of individual equipment capability healthiness shall be automated and systemized so that data reliability and healthiness determination reliability are to be improved. This also contributes to establish equipment quality improvement cycles.
While equipment data collection systems have been implemented for years at device makers for process condition data retrieval, equipment suppliers shall implement equipment engineering data collection and utilization system at their own manufacturing sites for proactive equipment quality visualization or enhanced equipment quality assurance with equipment capability level granularity.

Standard:
Data utilization for proactive equipment quality visualization shall be standardized in terms of the data and its data retrieval capabilities with individual equipment capability granularity and in order to promote efficient equipment engineering data utilization.

Remarks: None

Equipment engineering data definition

3.7. Equipment engineering data utilization areas of interest

Production equipment shall provide elemental data for the information used in the various equipment engineering operation areas.

Above-mentioned equipment engineering operation areas should include followings;

1. Management and control operations of the factory system view equipment behavior (GEM300)
2. Productivity management and improvement operations in terms of OEE, cycle time from the factory system view, equipment view, and, product wafer view.
3. Energy consumption management and reduction and consumables management and reduction operations
4. Process condition management, monitor, fault detection, and advanced process control operations where process parametric information is mainly used
5. Equipment engineering operations such as process tool healthiness monitoring, equipment capability performance validation, malfunction identification, maintenance management where equipment capability activity information is mainly used.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
The history has been that the equipment data is superimposed onto the SECS communication, and that the main data utilization purpose was to monitor the process conditions. Production equipment is the most precious resource in the factory, and consequently it is involved in many aspects of equipment engineering operations. The equipment engineering data shall be reexamined from above mentioned many aspects of relevant data usage.

Standards:
Equipment engineering data items, data types, and, relevant context data shall be standardized for each of the equipment engineering operations of interest.

Remarks:
It is note worthy to mention that equipment does not necessarily provide readily usable information for 5 operation areas. Since there are many data that are used commonly in the 5 equipment engineering operation areas, information extraction from the equipment engineering data shall be done external to the equipment in accordance with targeted operation areas of interest.

3.8. Equipment engineering data structure

The definition of equipment engineering data is designed in accordance with the logical modular structure per equipment's control capability logical structure.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers, device makers, and, software vendors

Background and purposes:
Equipment engineering data should be designed so that it is used both by the equipment suppliers and device makers for the purposes of equipment quality maintenance and improvement. Although the process parametric monitoring has been historically the center of interest at device makers, equipment data that more directly describes equipment capability activities is required from the viewpoint of equipment supplier.
The process performance of a production tool is hard to be described in terms of the process results since it is considerably dependent on process parameter settings and the wafer itself. Equipment quality should be visualized by visualizing individual capability performances. It should be understood that a production equipment is described as a logical combination of many individual equipment capabilities, and that some of these capabilities are common to other production equipment; i.e., an RF power application means is used in plasma CVD, PVD, dry etching tools. Design and utilization of equipment engineering data will be made efficient by standardized modeling of these equipment base capabilities.

Standards:
Equipment capabilities shall be described in a standardized hierarchical logical structure. Base equipment capabilities should be standardized for their behavior models comprising of data definition and healthiness model.

Remarks:
It is required that equipment engineering data is used per each of data utilization purposes with high efficiency. Information extraction from equipment engineering data should be well defined for automation without much labor. This means that equipment suppliers are able to gather data from the all process chambers delivered to users as needed and to evaluate the necessary part of the data with ease. If these are done by hand or with lots of mouse clicks, systematic and continuous equipment quality improvement will be jeopardized.

3.9. Equipment engineering data quality

Equipment engineering data shall be designed to suffice its data specification in accordance with individual data usage purposes. More concretely following 4 data qualities shall be considered;

(1) Data items and their precisions defined after healthiness models of individual equipment capabilities

(2) Sufficiency of context for equipment internal activity description endorsed with equipment activity event data

(3) Sufficiency in time stamping that allows correct interpretation of series of equipment activity accompanied by control sequential structure information

(4) Provision of context data from the viewpoint of equipment control sequence that helps a cluster of data be allocated in the right timing of equipment's control sequence data where that cluster of data is obtained external to the equipment control. Such "external data" gathering examples are data collection of supplemental equipment such as slurry supply units or fast trace data collection by dedicated data collector hardware such as an etching end point detector.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers and device makers, and, software vendors

Background and Purposes:
Although the specification of equipment engineering data cannot be determined uniformly since there are many different data utilizations and different tool types, equipment engineering data should be provided with the quality that assures correct data interpretation. This data quality corresponds to context data provision. Context data should enable data extraction of particular focused areas with the right logical state of equipment and recognition of start and end of a certain control sequence. Some equipment sequence context may be deduced from combination of plural equipment activity event data. Plural data sets with different time stamps with different clocks can be correctly interpreted by provision of adequate sequence context data. In other words very high time stamping accuracy would be required with less adequate context information (equipment activity event data) to read the data in some cases.
It is extremely important to note that the equipment should be correctly adjusted for their embedded capabilities' functions with using the clocks inside the tool and without factory system clock synchronization by equipment suppliers. Therefore EE data should be designed so that EE data can be interpreted correctly within EE data. Such concept of data usage on both side of the industry did not exist, and this concept is true enabler of considerable improvement of the equipment and related engineering activities.

Standards:
Data quality standard development is required whose scope includes interpretation of equipment engineering data with using the combination of time stamping and equipment control consequence information from the viewpoint of data utilization procedure.

Remarks: None

3.10. Focus on machine-to-machine/chamber-to-chamber differences

Equipment suppliers shall visualize process condition generation capabilities built in the equipment by equipment engineering data in accordance with the granularity that matches to the relevant sensitivity of the process with using reusable methods and referencing values. Equipment suppliers shall collect above mentioned equipment engineering data from the relevant process condition generation capabilities in all the shipment so that the data is to be statistically analyzed for reasonable management of chamber-to-chamber and machine-to-machine differences.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Equipment suppliers and device makers

Background and Purposes:
Process tools are designed to perform intended process execution of the relevant processes to the tools, validated, and, supplied to the market although there are many tool types and their processes to execute. Process condition generation means are to be validated for the stability, repeatability, and, fidelity to the instruction with the criteria at least through execution of the relevant best-known methods. The performances of the process condition generation means are to be compared with each other using these defined criteria over all the shipment. Statistical management of these equipment's process condition generation means at equipment suppliers is expected to encourage more rationalized management of equipment's performance to provoke further effective reduction of chamber-to-chamber or equipment-to-equipment differences at equipment suppliers.

Standards: None

Remarks: None

4. Individual Wafer Equipment Control

4.1. Graceful shutdown of production equipment

While production equipment is designed to have the densely scheduled processing over wafers so as to maximize the throughput, a production equipment shall cease processing wafers safely when malfunctions in safety or base equipment capabilities are detected within the minimum granularity unit such as individual wafers or individual chambers. The consecutive sequence from the decision making of ceasing processing to actual shutdown shall be reported.
(Ref.: EEC Guidelines 2002)

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Equipment suppliers and device makers

Background and Purposes:
The granularity of production tool's process ceasing action has not been standardized. It is important that the number of scrap wafers is minimized by designing production tools with minimum number of granularity of ceasing action.

Standards:
The process ceasing actions are to be standardized with considering the equipment types and variety of process status.

Remarks:
The malfunction of the equipment should be detected within the process time of the relevant chamber in multi-chamber tool. Processed wafers and unprocessed wafers are clearly recognized. Process ceasing method should be selected per information available from the tool, depending on tool/process configuration such as series or paralleled sequence in multi-chamber tools.

4.2 Equipment capability performance conditioning and adjustment not linked to wafer processing control

Equipment shall have a control means that allows either equipment internal control or external control to compensate equipment capabilities' performance variations where well established chronicle variation models are available. This control shall be delegated to the equipment by the factory system in an apparent procedure and the relevant compensation control activity shall be made visible to the factory systems.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Device makers

Background/purpose:
Equipment has well-known chronicle variations such as discharge impedance's decrease and its film growth rate change with a given power due to progress of erosion in the sputter target, and such as evacuation speed's decrease due to debris deposition accumulation inside the exhaust piping of CVD equipment.
This kind of stable and gentle change of equipment process performance still is specific to each of process chambers. Compensation control against such changes sometimes complicates the equipment control to unnecessary extent, and this is especially true for *small lot manufacturing* situations where much shorter time period of time is available to presetting such compensation parameters with knowing the destination process chambers for individual wafers compared to what it is for 25 wafer lot-based equipment control. Delegation mechanism of such compensation control to the equipment by the factory system eliminates such complication.
This mechanism would allow simple recipe operation without describing the compensation parameters in detail per individual chambers or equipment differences.
This kind of compensation is often done implicitly by equipment itself, but the compensation needs to be explicitly delegated and the compensation activity needs to be explicitly visualized.

Standards:
For the compensation, the logical interface needs to be standardized.

Remarks:

4.3 Continuous wafer feeding and pick-up

Equipment shall support operation using different *input carriers* and different *output carriers* to realize continuous feeding of unprocessed wafers to the process part of a tool and pick-up of processed wafers. Such operations shall include operations of dividing or mixing groups of wafers into *output carriers* as required. Equipment and the factory system shall mutually exchange the necessary information in order to pick-up unloaded *input carriers* and to feed carriers to load the processed wafers.
Who to implement this guideline: Device makers and equipment suppliers
Who to use this guideline: Device makers

Background/purpose:
In case of equipment which has relatively large number of process positions, such as linked lithography equipment , unloaded empty carriers may occupy the load ports waiting for the processed wafers originated from these individual carriers to come back while they have no further unprocessed wafers to feed to the process part of the equipment. Furthermore AMHS is prevented from feeding carriers loaded with unprocessed wafers due to the occupation of load ports by these carriers. Although such phenomenon would be eliminated if sufficient number of lord ports are provided, it is not usually practical to widen equipment's physical width of the front end to accommodate large number of load ports. One solution is to virtually increase the number of lord ports, by replacing the empty carriers with new carriers loaded with unprocessed wafers so as not to discontinue wafer feeding while collecting the processed wafers into designated empty carriers. Loaded carriers are to be picked up at appropriate timings by AMHS so that the flow of processed wafers is not disturbed. This GL is intended to encourage such solutions for productivity recovery.

Standards:
In addition to the uni-cassette operation already defined in GEM300, the above mentioned operation scenarios or likes of equipment need to be standardized.

Remarks:

4.4 Wafer-level over-taking control in batch processing equipment

Batch process equipment with the internal buffer shall be capable of accepting *hot wafers* until the reserved process is started by the instruction from the factory system.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Device makers

Background/purpose: Batch equipment such as oxidation/diffusion, cleaning, and low pressure-CVD is one of the biggest obstacles to achieve reduction of hot wafer's cycle time. Operations below would enable reduction of hot wafer's cycle time. This would be a large positive impact to SoC business.

- In the case where reserved *fill-dummy wafers* for the scheduled batch can be replaced with *hot wafers,* new process starts after batch formation is repeated for the new set of wafers.

In the case where product wafers for the scheduled batch can be replaced with *hot wafers* or where *hot wafers* can be simply added to the scheduled batch, the new process starts after batch formation is repeated for the new set of wafers.

Standards:
Wafer-level over taking scenarios and its controlling methods need to be standardized for batch equipment.

Remarks:

4.5 Wafer-level intermediate process quality confirmation (Phase3)

4.6 Wafer-level processing quality management (Phase3)

4.7 Productivity of inspection and metrology tools (Phase 3)

5 Production Equipment Productivity Improvement

Definition of Dandori

Dandori operations are peripheral operations to the throughput-constraint main thread operations. *Dandori* operations include preparatory operations before the processing, post process operations, wafer transportations to the process tool or to the process part of the tool, and, wafer identification operation.
Dandori operations may be categorized per operation responsibility owners;
Class 1 *Dandori* operations: where operations are all delegated to the equipment and designed by equipment suppliers to be executed within that production equipment.
Class 2 *Dandori* operations: where operations reside across the boundary of factory and the production equipment, and they are very often related the information transfer.
Class 3 *Dandori* operations: where operations are controlled by the factory system.

5.1 Dandori visualization

Dandori operations shall be categorized for the ease of solutions development by device makers and the equipment suppliers. The categorized *Dandori* operations shall be defined with provision of the states and their triggers. *Dandori* data shall be designed for a structure so that the factory system and the equipment can share for control synchronization.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
Dandori operation elimination or its time reduction, paralleling *Dandori* operation with the main thread operations, evaluation of effectiveness and related effects of *Dandori* operations are to be considered for improvements in cycle time and OEE.
Historically *Dandori* operations have not been well categorized and defined per their logical location affiliations such as equipment side, factory side, and their boundary.

Standards:
Dandori operations should be defined and categorized in standard.

Remarks:
Figure 3 shows list of counter measures examples against productivity losses due to *Dandori* operations where the operations are categorized per owner of the operation.

Category	Improvement in Specific Technology	Improvement in Control Technology
Class 1	• Reduce seasoning and/or cleaning time • Reduce WIP identification time	• Optimize tool internal wafer transfer scheduling • Optimize tact balance between equipment side and factory side
Class 2	• Reduce process instruction information time • Reduce WIP identification time • Reduce carrier identification time • Reduce NPW preparation time	• Parallel such operations as seasoning and cleaning with other operations • Preset the process instruction • Optimize the wafer process order
Class 3	• Reduce carrier dispatching time • Reduce time used for equipment process performance stability • Reduce time used for product quality confirmation	• Pre-create of NPW process jobs • Synchronization of job exchange and dispatching • Parallel product quality confirmation operations and other operations

Figure 3: Counter measure examples for productivity losses by *Dandori* operations

5.2 Dandori control from the factory system

Equipment shall be equipped with a capability that allows the factory system to instruct *Dandori* operations on the equipment. The above control information shall be designed for a reasonable structure.

Who to implement this guideline: Equipment suppliers and device makers
Who to use this guideline: Device makers

Background/purpose:
Implementation of such capability that allows manipulation of *Dandori* operations on equipment will provide the same degree of controllability in sequence manipulation and visibility to the factory system as the processing execution, and it is expected to contribute to improvement of equipment productivity.

The information on scheduled *Dandori* operations on equipment as well as wafer processing needs to be communicated with the factory system.

Standards:
The control interface of *Dandori* operations needs to be standardized.
The instruction information of *Dandori* operations on equipment needs to be standardized.

Remarks:
Readers should refer to the requirements on wafer processing order manipulation.
Dandori operations simply repeated on equipment would not be of interest for the factory system, and, therefore, the operations are often delegated to the equipment. The equipment needs to have two such simplified controlling functions; delegation of such *Dandori* operations to equipment and triggering the start of such *Dandori* operations.

5.3 Continuous wafer processing across lot boundaries

Single wafer processing equipment shall be able to process wafers with the minimum production discontinuity across lot boundaries over different process lots as the equipment's process resources become available for the following lot.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Device makers

Background and purposes:
There are often observed unnatural discontinuity in production time of individual wafers across lots with different recipe contents.
Equipment needs to wait for a tool internal processing resources to become available to the wafers of the following lot (such cases as bake temperature setting change from one value to another across the lot boundary).
This guideline intends to encourage that the wafers in the subsequent lot will be processed without excessive delay so as to minimize the discontinuity in the production time.

Standards:
Standards for single carrier multi-lot capabilities need to be reinvestigated

Remarks:
Production discontinuity can also arise where continuous wafer supply from the load ports is not possible. The requirements in 4.3 should be referred.

5.4 Intended stable wafer processing

A single-wafer processing tool shall conduct the identical processing to each of the individual wafers within a lot or across adjacent lots as intended.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
There are many factors beside what is written in a recipe that determine the process condition in process tools. A good example is the condition observed by the wafer between the 2 adjacent process steps in a multi-chamber configuration tools. It is important to understand the process conditions for the wafer between chambers such as wafer's waiting time on robot blade between steps, environment the wafers are exposed, temperature decrease, etc..
Process tools are expected to provide identical process execution to all wafers within a lot, or even for wafers in different lots with the same processing conditions in accordance to the equipment design concept for what is written in the recipe and what is not necessarily written in the recipe as well.

Standards:
None

Remarks:
Some process tools are designed to use plural process chambers in parallel, and in such cases, chamber-to-chamber differences are to be sufficiently reduced together with above mentioned effort to conduct the identical processing to the wafers.
Equipment control for identical wafer processing is to be visualized and can be validate as required.

5.5 External utilization of equipment internal counter information

1. Life time progress information and state of consumables in the equipment shall be made externally accessible.
2. Setting values and current observed values of equipment's interlock capabilities shall be made externally accessible.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:

Equipment maintenance planning or scheduling is one of the basic equipment engineering operations. The lifetime progress information of the consumables in the equipment is very important to this operation.
Systematic confirmation of resetting consumables' lifetime counters after maintenance work is effective to prevent equipment's accidents and/or malfunction happenings that has pronounced high occurrence tendency especially after maintenance work.
Conformance confirmation of the setting values of interlock capabilities against the normal values is also effective to prevent equipment's frequently happening accidents after maintenance work. Systemizing above mentioned confirmation procedures are important.

Standards:
Data items and data access methods need to be standardized.

Remarks: None

5.6 Efficient operation of multi-chamber equipment

Each of equipment's process positions, process stages, or, process chambers shall be designed to have its process acceptance state attribute. This state value shall be set and utilized by the factory system.
Process acceptance status are of that the chamber can process all processes designated to the equipment, that it can process some restricted processes, that it cannot process any product wafers but monitor wafers, or, that it can process only non-product wafer like dummy wafers. The change in the status shall be reported to the factory system.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Device makers

Background and purposes:
In multi-chamber tools the whole operation is sometimes restricted to unnecessarily confined operations depending on state of one of the chambers, and different recipes may be needed to be given depending on the availability change in one of the chambers for the execution of the same process.
. The utilization summary data of multi-chamber equipment cannot be fully used because of the data's rough granularity in the state expressions.
It is anticipated that processing of production wafers in the normal state process chambers and processing such as chamber seasoning with non-product wafers are required to undergo simultaneously especially in multi-camber equipment.
A process chamber can be managed with the smaller engineering effort under most of its various status such as those during the recovery operation of equipment after maintenance such as seasoning and in the process of qualifying for production, in the full capability if individual chamber's availability state values are set by the factory system with reasonable granularity. The equipment would be able to combine these process position status and the attribute of incoming wafers so that partial maintenance of that tool is made possible.
Useful data acquisition will be possible especially for multi-chamber equipment.

Standards:
The instruction method of setting availability status from the factory system needs to be standardized.

Remarks: None

6 New Factory-Production Equipment Control Interface

6.1 Addition of wafer-level management interface

Following information shall be defined across the interface where individual wafers are transferred to process part of the production equipment. This information shall be shared with the system external to the equipment.
The information to be handled is as follows;
Wafer identification information, wafer traceability information with its elements such as process sequences log data for individual wafers, wafer rotation at relevant wafer positions, equipment group, tools, equipment modules that individual wafers went through, carriers in which that wafer was loaded, processing instruction information such as the recipe, *Variable Parameters,* process positions.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Equipment suppliers and device makers

Background and purposes:
In high-mix production various process/chamber configuration and operations are possibly used. Therefore process management requires the granularity of individual wafers and individual processes used. Although the uni-cassette operation has been implemented for many years where carrier integrity and slot integrity are well managed at hardware level, such integrities will be possibly subjected to change in response to the wafer-level control of the next generation fab. Such elaborate management will be eventually lead to optimization of wafer feeding into individual process parts of the production equipment in terms of stable process and productivity control including cycle time reduction. This guideline is a basic prerequisite requirement to individual wafer-level manufacturing control.

Standards: None

Remarks: None

6.2 Wafer-level equipment control interface

Equipment shall be equipped with a capability that allows the factory system to manipulate the wafer processing queue and equipment's *Dandori* operation queue.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Device makers

Background and purposes:
There is often observed necessity to improve equipment productivity by changing the wafer processing order which enables reducing process changes and reducing *Dandori* operations between process operations. The wafers of interest are those physically and/or logically given to the tool. Such control of the factory system virtually enables the single wafer production control.
Wafer processing order is may be changed within one carrier, or among different carriers. The manipulation of wafer processing order should be possible at the latest occasion so that the chance to accept the queue manipulation is large to retain the higher degree of productivity improvement

Standards:
Queue operation already defined in GEM300 needs to be reinvestigated and extended.

Remarks:
Readers should refer to the requirements of *Dandori* control from the factory system.
The factory system needs to schedule *Dandori* processing together with the wafer processing order.

Equipment needs to upload the following data to the factory system so that the factory system is able to decide the next processing wafer.

1. Scheduled process end time of wafers being processed
2. Anticipated process end time of reserved wafers
3. The load ports and/or internal buffer shelves that are planned to be made available to the next wafer(s)
4. Anticipated *Dandori* operations and their information for the next available wafer(s) such as recipe download and conditioning the equipment
5. Next wafer's anticipated process start and end time

6.3 Wafer-level traceability in production equipment

Equipment shall be able to trace each of the wafers even on an event in which wafer processing queue is modified.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Device makers

Background and purposes:
Currently in most of the cases wafers are processed per slot number order and they are returned to the same slot of the same carrier; they are called “slot integrity “and “carrier integrity”, respectively.
Because of the productivity reasons it is sometimes necessary to change wafer’s processing order. Some operations require different output carriers from the input carriers or different output slots from input slots. The ability to trace the wafers with accurate log data on wafer-by-wafer basis becomes extremely important for such operations.
The factory system needs a certain time to update the wafer trace information. For the implementation of wafer-level control the latest information is required in a real time manner for high granularity process control, and equipment should be able to provide to the latest trace data for fast control purposes.

Standards:
The wafer traceability provided by equipment needs to be standardized. Several standards need to be prepared according to different operation scenarios which include reading wafer ID and using it for control.

Remarks: None

6.4 Processed wafer and unprocessed wafer notification

Equipment shall clearly distinguish processed wafers from unprocessed wafers, and report the relevant information to the factory system upon urgent process shutdown.

Who to implement this guideline: Equipment suppliers
Who to use this guideline: Device makers

Background and purposes:
When equipment urgently shuts down processing, equipment needs to clearly distinguish the properly processed wafers, the likely improperly processed wafers, and the unprocessed wafers. Equipment needs to conduct wafer collection and recovery actions to the normal condition. This requirement is extremely important under such occasions.

Standards:
The notification method of the above mentioned information needs to be standardized.

Remarks: None

7 Guideline Phasing

The guideline items marked as Phase 3 in the contents will be developed after January 2008 and revision 3 J300P guidelines will be published

8 Contacts

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9 Revision Record