SEMI T18-1106 (Reapproved 0718)
SPECIFICATION OF PARTS AND COMPONENTS TRACEABILITY

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1 Purpose

1.1 The purpose of this Document is to provide standard means to collect and manage data to estimate lifetime or remaining time before such maintenance as calibration, cleaning and replacement more accurately.

1.2 The final goal of the Standard is to realize the traceability of semiconductor, flat panel display (FPD), or MEMS devices with tracing parts and/or components of their manufacturing equipment, including jigs and some consumable materials.

2 Scope

2.1 This Document specifies fundamental functions and messaging capabilities on equipment and its supervising systems, based on SEMI T12 (Specification for Tracing Jigs and Implements) with some extension.

2.2 This Document doesn't specify the methodology or algorithm to estimate or foretell the lifetime of parts and components. The components here include such consumable materials as sputtering gun with target material and repeatedly used chemicals in bath or container.

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 This Document is written to be applied to production lines for semiconductor, FPD, or MEMS devices including manufacturing equipment in the lines. Appling to the other production lines such as print circuit board (PCB) assembly systems could be possible if specific differences to the system are taken care of. The original concept in this Document is limited to the semiconductor, FPD, or MEMS device production system.

4 Referenced Standards and Documents

4.1 *SEMI Standards and Safety Guidelines*

SEMI E5 — Specification for SEMI Equipment Communications Standard 2 Message Content (SECS-II)

SEMI E30 — Specification for the Generic Model for Communications and Control of Manufacturing Equipment (GEM)

SEMI E98 — Provisional Standard for the Object-Based Equipment Model (OBEM)

SEMI T12 — Specification for Tracing Jigs and Implements

4.2 *Object Management Group (OMG) Standards*[1]

Formal/05-07-04 — Unified Modeling Language (UML): Superstructure version 2.0

Formal/05-07-05 — Unified Modeling Language (UML): Infrastructure version 2.0

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

[1] Object Management Group (OMG) 140 Kendrick Street, Building A, Suite 300, Needham, MA 02494, USA; Telephone: +1.781.444.0404; Fax: +1.781.444.0320; Website: http://www.omg.org

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5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 None.

5.2 *Definitions*

5.2.1 *component* — decomposed unit of equipment. The unit may be essential for the equipment or may be optional. UML modeling component is another meaning; it is often described with italicized Arial (Helvetica) font as *component*.

5.2.2 *consumable part* — such consumable as bonding wire held on equipment in container or magazine, or such limited repeating-time used consumable on equipment as chemicals periodically supplied by factory. Familiar examples in home and office are ink/toner cartridges or dot-impact ink ribbons. While it is a specific type of part, often it could be a sort of materials or jigs. Or otherwise it is one of subcomponents of equipment.

5.2.3 *part* — replaceable or maintainable unit, or a set of the units on equipment. From the point of traceability, this is the general name of jigs, components or consumable part.

5.2.4 *jig* — an attachment which is used to support measurement or production of material on one or more equipment as defined in the SEMI T12.

6 Convention

6.1 This section defines the conventions followed by this Document.

6.1.1 *Object Conventions* — This Document conforms to the conventions for objects established by SEMI E39, including object diagrams, object terminology, and requirements for standardized objects. Accordingly, notation is based on Unified Modeling Language (UML).

6.1.1.1 *Formal Name of an Object* — The text capitalizes formal object name references. Similar to the way capitalization is normally used when discussing entities. When describing something in the general (like cities) lower case is used, but when a specific entity is of interest (New York City), then first letters are capitalized.

6.1.1.2 *Components of Complex Attributes* — The names of object attributes defined in tables are left-justified. The individual elements of complex attributes are right-justified in order of appearance below the complex attribute.

6.1.2 *State Model Conventions*

6.1.2.1 This Document uses the Harel state chart convention for describing dynamic operation of defined objects. The outline of this convention is described in an attachment of SEMI E30. The official definition of this convention is described in "State charts: A Visual Formalism for Complex Systems"[2].

6.1.2.2 The Harel convention has not the concept of state models of 'creation' and 'extinction' for expressing a temporary entity. No such entity is described in this Document so far, but it is reserved for reference and future extension. If it is specified in this Document, a copy of the same state model is used for such an independent entity newly created. In the diagram, a circle with a black circle inside is used for expressing extinction of an entity. A filled black circle denotes the entry to the state model (the entity creation).

6.1.2.3 Transition tables are provided in conjunction with the state diagrams to explicitly describe the nature of each state transition. A transition table contains columns for Transition number, Previous State, Trigger, New State, Actions, and Comments. The 'trigger' (column 3) for the transition occurs while in the 'previous' state. The 'actions' (column 5) includes a combination of:

1. Actions taken upon exit of the previous state.
2. Actions taken upon entry of the new state.
3. Actions taken which are most closely associated with the transition.
4. No differentiation is made between these cases.

[2] D. Harel, "State charts: A Visual Formalism for Complex Systems", Science of Computer Programming 8, 1987.

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Num	*Previous State*	*Trigger*	*New State*	*Actions*	*Comments*

6.1.3 *Service Message Representation* — Services are functions or methods that may be provided by either the equipment or the host. A service message may be either a request message, which always requires a response, or a notification message, that does not require a response.

6.1.3.1 *Service Definition*

6.1.3.1.1 A service definition table defines the specific set of messages for a given service resource, as shown in the following table:

Message Service Name	*Type*	*Description*

6.1.3.1.2 Type can be either 'N' = Notification or 'R' = Request & Response.

6.1.3.1.3 Notification type messages are initiated by the service provider (e.g., the equipment) and the provider does not expect to get a response from the service user. Request messages are initiated by a service user (e.g., the host). Request messages ask for data or an activity from the provider. Request messages expect a specific response message (no presumption on the message content).

6.1.3.2 *Service Parameter Dictionary*

6.1.3.2.1 A service parameter dictionary table defines the description, format and its possible value for parameters used by services, as shown in the following table:

Parameter Name	*Description*	*Format: Possible Value*

6.1.3.2.2 A row is provided in the table for each parameter of a service.

6.1.3.3 *Service Message Definition*

6.1.3.3.1 A service message definition table defines the parameters used in a service, as shown in the following table:

Parameter	*Req/Ind*	*Res/Cnf*	*Comment*

6.1.3.3.2 The columns labeled Req/Ind and Rsp/Cnf link the parameters to the direction of the message. The message sent by the initiator is called the 'Request'. The receiver terms this message the 'Indication' or the request. The receiver may then send a 'Response' which the original sender terms the 'Confirmation'.

6.1.3.3.3 The following codes appear in the Req/Ind and Rsp/Cnf columns and are used in the definition of the parameters (e.g., how each parameter is used in each direction):

M	Mandatory Parameter — Must be given a valid value.
C	Conditional Parameter — May be defined in some circumstances and undefined in others. Whether a value is given may be completely optional or may depend on the value of the other parameter.
U	User-Defined Parameter.

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-	The parameter is not used.
=	(For response only.) Indicates that the value of this parameter in the response must match that in the primary (if defined).

7 General Requirements

7.1 *Means to Confirm Installation* — Equipment has to confirm the points where anticipated parts are installed physically and logically on the equipment. Also it has to be identified logical functionality of the parts what general role they are expected. To confirm and identify, the reference model of the equipment shall be SEMI E98 (Object Based Equipment Model).

7.2 *Means to Identify* — Equipment has to have any means to identify the parts. They may be such physical reader for radio frequency tag or bar code, known architectural/composition configuration data on equipment, information from its management system, suggestion/selection by its operator and so on.

7.3 *Means to Communicate* — Each piece of equipment and its managing system has to have any electric communication means to transact each other, to realize the purpose of this Document.

8 Overview

8.1 *Parts for Semiconductor Manufacturing Equipment* — A semiconductor production line consists of many amount pieces of equipment with many different types. Some types of equipment require such parts as jigs, and they often have maintainable/replaceable components as well, to manufacture semiconductor devices. Quality, yield or productivity of process may depend on them and their management, for some of them act very important roles.

8.2 *Management of Parts* — Some of the parts require management including their life/maintenance time to have better product quality, yield and productivity. This Document specifies definitions, concepts, behavior and services to manage the parts on equipment and also in factory. However, not all the parts require such management, and specification of this Document should be applied restrictedly, especially to the ones used for important processes, sensitive and incompatible combinations between the parts and equipment.

8.3 *Effective concepts for a Variety of Parts* — There are many kinds of equipment types in the line and also a variety of parts dependent to the type and/or model of equipment, and additional specification requested by its customer. For higher possibility to be effective to almost all of them, specification of this Document is generic and idealized without any physical limitations or practical details. It is also important to be independent to rapidly changing technologies and production environment.

8.4 *Logical and Informational Specification* — To keep track of conceptual document and keep shareable area as wide as possible, this Document specifies just logical and informational issues, except related information part. Physical specifications are assumed to be defined as separated documents; they may be specified in other standards, specific Subordinate Documents of this Standard, propriety specifications or mixed together.

8.5 *Tracking Oriented Management* — Because there may be very specific managements or operation for strategies in factories and they may not be shared by many fabs, strategic management for specific factory or products may not be better to be standardized but often they can be applications of this Standard. Because the management specified in this Document are specified for traceability, “Jigs and Components Traceability” could be considered as “management of Parts.”

8.5.1 *Traceability of Parts* — In a semiconductor manufacturing factory, it is necessary for some parts to be managed for the purpose of traceability.

8.5.1.1 *Delivery and Use* — There are two types of information to track Parts. One of them is transferring information (e.g., where it is and who use it). It is required to discriminate between logical information and physical attachment. The other is historical information of the Part (e.g., how much it was used, what process conditions were applied, when it was repaired or maintained, what its state is).

8.5.1.2 *Dispatching and Receiving Parts* — Such an attachment as Jig or Implement is transferred from stock yard to equipment or the other way and may be shared between two pieces of equipment. At the time it is picked up at source location for destination, the fact should be reported to Tracking System. When it arrives at the destination, this fact is

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also required to be reported to the system. Verification has to be done at the destination before it is dealt (e.g., process, maintain or stored). If a problem happens during transportation, an exception is raised.

8.5.1.3 *Consuming/Degrading Fact for History Record* — When it is used on equipment (e.g., for process or maintenance) its history information is accumulated and the information is reported to the system at every milestone. Examples of the history information are time duration, cycle time, such process parameters as temperature and pressure, material characteristics and known damage occurred during the process.

8.5.1.4 *Reassigning Jigs on Reported Data* — The tracking system summarizes reported information. Clients of the system may inquire the information. One of the clients may be scheduler/dispatcher and it may change process machine for specific material to get better product quality.

8.5.1.5 *Event Data to Prevent Parts Expiration* — A client may ask target equipment to handle specific event which shows reaching limited cycle time for a jig on the equipment. Expected handling for the event, for example, is to stop processing. The client may ask to pause before starting a lot if current cycle time of the jig is very close to expiration cycle time. The tracking system and equipment should cooperate together to predict reaching the expiration

8.5.1.6 *Compositing Components of Equipment* — If it is a component rather than Jig or Implement, similar tracking efforts are made. But prime responsibility is not tracking system but equipment itself or the tracking system on equipment because components may not be shared between a few pieces of equipment.

8.5.1.7 *Management of Parts* — If it is Consumable Parts, equipment or tracking system needs to arrange replenishing, renewing or reducing exhaustion to avoid running out of resource, expiration of validity or malfunction of the parts.

8.5.1.8 *Demeanor of Parts in Use* — While parts are working regardless whether it is actual process, setup, standby or any kind of operation, such demeanor as servo current or settling time may be acquired. A part of such behavior data may be possible information for life time estimation. Similar idea may be applied to such consequence as calibration error, setup retry times or environmental recovery parameters monitored or inspected in equipment.

8.5.1.9 *Inspection/Repair Information* — Some process equipment may have inspection subsystem for jigs or materials. In-line/off-line inspection subsystems including inspection/repair tools are expected to transfer such result information to traceability data server/manager, bring it back to equipment/stock yard with the parts, and/or recorded to inventory. This demand may not be dependent to physical location of the tools or their capability and style even if the capability is embedded on a piece of equipment.

8.5.2 *Application of Tracking System* — Because this Document specifies basic capability of tracking Parts, specific applications for semiconductor device manufactures or equipment suppliers, but such advanced applications as securitized tracking are out of scope of this Document. Using this basic specification, expecting advanced capabilities can be realized with combination of additional capabilities supplied by equipment users, equipment suppliers or system suppliers.

8.5.2.1 *Estimation Capability Anywhere* — While life time estimation capability may not be specified on this Specification as scoped in § 2, it or its portion may be located in traceability server/manager, equipment data acquisition (EDA) system, inventory, manufacturing execution system (MES), cell controllers, on a piece of equipment and so on.

8.5.2.2 *Total Traceability and Parts Lifetime for Preventive Maintenance* — Parts Lifetime may be estimated and managed based on collected traceability data specified in this Document. The estimation capability may help keeping process quality better, higher yield and better overall productivity rate of equipment as the benefit of the final application. The traceability data including lifetime estimation information ends up the source of Die Trace/Device Tracking system specified in SEMI T13.

9 Concepts

9.1 *Extending SEMI T12 JIT* — One of the fundamental data source to estimate parts lifetime is History Record or History Database (HistoryDB) of SEMI T12 if the standard is applied to corresponding parts as the derivatives of jigs or implements. This Specification stands on the standard and starts with extending its scope for this Specification.

9.1.1 *Derived Attachments* — Basic feature of attachment, that is jig or implement, is something different from that of non-attachment parts. In spite of that, difference of the nature for maintenance cycle, remainder until limit or lifetime between the both is little. Based on this fact it is very natural to apply SEMI T12 to any parts regardless whether they are attachments or not. It is expected to derive the attachment to general parts and extend the standard

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to support lifetime management capability. This Document review SEMI T12 to make which part is extended and how it is done.

9.2 *Subclasses of Attachment* — General traceable part is modeled in this Specification as subclass of Attachment defined in SEMI T12, as discussed above.

9.2.1 *Attachment* — Before discussing subclasses, this subsection reviews base of attachment here. Such parts as deposition shields, furnace tubes, carriers, reticles and probe cards have the characteristics of attachment which is used to process product materials, prepare the process, calibrate/adjust process stations and so on. Accumulated time of use/cycles control, suffered unexpected severe conditions, frictional wear, defect levels, contamination may make product devices poor, lower grade or useless, or production with bad yield. The purport of traceability is to help reaching root cause, controlling quality and/or prevent fault in process by tracing, recording or managing of such deterioration nature of the attachment.

9.2.2 *Receding Material* — Material other than major part of product is also to be managed. Sputtering target, for example, requires to be managed consumption amount, non-uniform erosion, contamination, cracking and so on. Estimating its lifetime allows avoiding negative process conditions, and/or trends of such condition may suggest variation of the lifetime. The nature of this kind of parts is closely resemble to that of attachments on use and management because they are used around pieces of equipment, refilled/regenerated and stocked in storage. While some of them can be identified by IDs of such container as cartridges, magazines and spools, sometimes they may not have specific containers and filled up or supplied from reservoirs through pipeline. Besides such continuously supplied fluid or powdery consumable material as sputtering gas and polishing slurry with supply lines automatically or manually, they could be identified by their holding entities with supplied time even if they are contained in persistent components or containers and supplied intermittently.

9.2.3 *Traceable Component* — Such small components as ion gauges and lamps are exchanged from time to time when they are malfunctioned or losing required capability. They are components but a kind of consumable in the sense. Often equipment or unit suppliers design for easier replacement. Even if they didn't design appropriately, they must be Traceable Components if the nature of the component needs periodical replacement with spare parts.

9.2.4 *Persistent Component* — On the other hand process chambers and substrate transport systems/chassis are not usually replaceable or difficult to replace. However they are still really components of a piece of equipment and should be kept better condition with persistent efforts whenever maintenance task is expected or repair work is required. Besides breakdowns due to accidents, healthy period until expected maintenance work could be considered as a kind of provisional lifetime of Persistent Component. It is the part which is not stored in stockers nor registered to inventory.

9.3 *Parts Lifetime Traceability Model* — With above subclasses Jig/Implement Traceability model diagram introduced in SEMI T12 as Figure 1 is updated as below. Class Attachment has a couple of intension there in SEMI T12: abstract attached units and ancestor of Jig and Implement. The ancestor role is renamed here as the class JiAttachment to separate from the abstract part in the following diagram. On the other hand the abstract nature is also renamed to 'Part' from Attachment, with more generalization for all of JiAttachment, RecedingMaterial, TraceableComponent and PersistentComponent. As described above RecedingMaterial and its mirror object SecondedSMaterial on equipment may be contained or mounted in/on foreign container, separated carrier or some component of equipment (see the diagram). Because they may be consumable material or unidentifiable entities, they are to be identified with such holders.

9.3.1 *Carried Classes* — Besides Secondment all introduced classes carried over from existing SEMI T12 are not changed at all in this Document. Unless additional or revising description is specified in this Document, all classes and objects are defined as same as SEMI T12. Description of the part is not repeated here.

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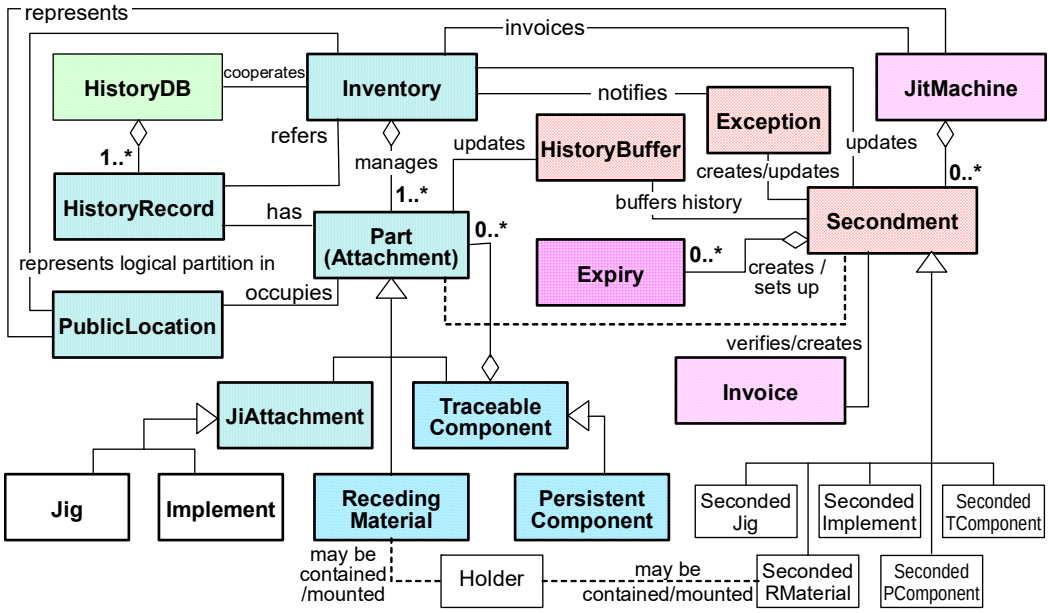

Figure 1
Extended Attachment Tracking (Parts Traceability) Model for Lifetime Management

9.3.2 *Part* — This class was referred to as Attachment in SEMI T12. It is more generalized with services for possible holder identification. For such items as powdery material, emulsion, liquid or gas, can be split and managed in containers. They may be sometimes identified by the containers or holder's ID and type. Such chunked material Pellets and chips may be included in the kind of the items. Even for solid materials as sputtering target may be identified by its mount or assembly frame ID.

9.3.2.1 *Responsibility of the Part* — All objects instantiated for the class Part have almost the same responsibility as Attachment's in SEMI T12. It holds and organizes such traceability information as history of corresponding entity for the object.

9.3.2.2 *Services of the Part* — All the services of the class Part are carried over from the class Attachment in SEMI T12. Signatures of the services are also the same, besides actual information given by values of the variables defined in the signature.

9.3.2.3 *Behavior of the Part* — This class has almost same behavior as one of the class Attachment in SEMI T12. It aggregates and keeps HistoryRecords, occupies PublicLocation and managed by Inventory, requested by some other entities for collaboration as described in SEMI T12 for the class Attachment. This class is stateless as well.

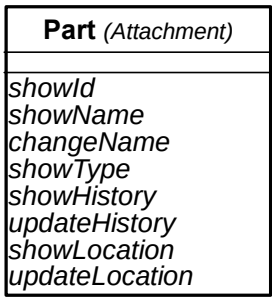

Figure 2
Part Class Diagram (Interface Model): Attachment Class in SEMI T12

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9.3.3 *Secondment* — This class represents the physical entity on equipment corresponding to the Part as the relation between the Secondment and the Attachment in SEMI T12.

9.3.3.1 *Responsibility of the Secondment* — This class is physical representation of the Part during actual part is brought or installed on equipment. It maintains information happened on the physical entity corresponding to the Part and watches its expiration.

9.3.3.2 *Services of the Secondment* — Following diagram illustrates the class Secondment with its services. It is completely same as the same name class in SEMI T12 and the nature including services is carried over from the class, except values brought by the services corresponding to the introduction of subclasses of the class Part. For example, returned ID may be holder's ID with timestamp/serial code for some RecedingMaterials. If the Secondment is a composite component, its state including expiration may be reflected by its subcomponents' states.

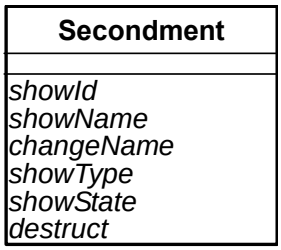

Figure 3
Secondment Class Diagram (Interface Model): Same as in SEMI T12 (just for reference)

9.3.3.3 *Behavior of the Secondment* — This class has almost same behavior as the class Secondment in SEMI T12. It's created on equipment when a physical part is handed, supplied or installed to the equipment with the property based on the information in Invoice. It aggregates Expiry for monitoring expiration, has history buffer to keep tentative history fragments, and keeps Exception during exception state is effective, as described in SEMI T12 for the class Secondment. This class has a couple of states in parallel as same as they are in SEMI T12.

9.3.3.3.1 *Variance Related to a Kind of Components* — Some difference from SEMI T12 may come from the possibility of composition of a Part with the other Parts. Expiration may be some combination of composite Parts. If the Secondment is a kind of component which consists of more than one Parts or Secondments, its state is compound of their states.

9.3.3.3.2 *Variance Related to Non-JiAttachments* — If the Secondment is not a kind of JiAttachment, the invoice may not be communicated before arrival of the physical Part. In such cases the first historical event is sent first with some pseudo ID and/or name, and then the invoice information is given to the equipment. The Secondment changes the attribute(s) at that time.

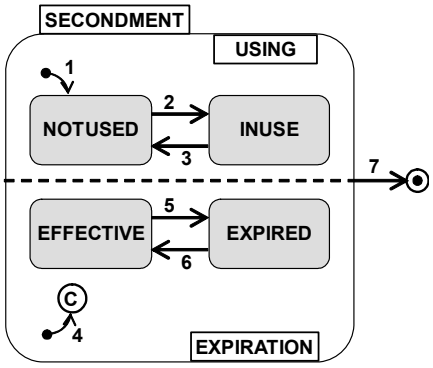

Figure 4
State Diagram of Secondment Class (just for reference)

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9.3.4 *JITMachine* — This class represents a piece of equipment to trace parts as almost same as the same name class in SEMI T12. Scope of trace capability of the JITMachine is interpreted as all expected parts including components on the equipment. This class creates Secondment and such related non-perspective objects as HistoryRecord when corresponding physical part entity is identified.

9.3.4.1 *Responsibility of the JITMachine* — This class creates non-persistent objects as described above. If a Part is such fully inventory managed items as JiAttachments, Invoice object is created when invoice communication to tell information of dispatched item to be received. If not, the object is created when a physical Part entity is identified. The latter case include such RecedingMaterials as sputtering targets, fluid material through supply lines or bottles, rolled wire and so on. Such TraceableComponents as ion gauge and PersistentComponents may be also included unless they are fully managed in inventory. Verification of these types of parts is always successful because the piece of equipment and factory managing system or inventory may not be notified about the delivered Part in advance. At the time the successful verification result is communicated, the inventory is aware of that and updates its history.

9.3.5 *Subclasses of Part* — The subclasses of the class Part inherits the nature of the class. They may have some variation comes from restriction specific to the subclass, extension dependent to the subclass, or the both. However, they keep most of the original nature which the class Part has, in order to be a kind of Part.

9.3.5.1 *JiAttachment* — This class represents Jig or Implement defined in SEMI T12, and this class is as completely same as Attachment in SEMI T12 except the original name was devolved on the generalized class and renamed to JiAttachment. This class keeps the original service or interface usually. Often holder related services may not be used for this subclass, or holder including container type shows the same ID as its content JiAttachment's.

9.3.5.2 *RecedingMaterial* — This class represents any non-substrate material but that is consumed or catalytic during process. Sputtering target, slurry and gas supply are examples as described before. For such materials as monitor pieces are treated as a kind of JiAttachment. In contrast to JiAttachment, holder related services are often used for this subclass and tracing system sometimes substitutes the holder ID is for material identification. If the material is refilled to holder or container after exhausted or expired previous material is dumped, the ID should be represented with such suffix to make uniqueness as timestamp or serial code. Otherwise replacing content material is required to be recorded as a part of its history. While the system focuses into subdivided unit in the former case, it does into the holder in the latter case.

9.3.5.2.1 *Responsibility of the RecedingMaterial* — Besides holder information, this class has the same responsibility as the super class Part has.

9.3.5.2.2 *Services of the RecedingMaerial* — The diagram below illustrates the class RecedingMaterial with its services. Services carried over from the class Attachment in SEMI T12, that is equivalent to Part in this Document, are italicized to emphasize inheriting and regular ones are appended to specialize this class with regular font.

9.3.5.2.3 *Behavior of the RecedingMaterial* — This class has almost the same behavior as the one of the class Attachment in SEMI T12 or Part here. It aggregates and keeps HistoryRecords, occupies PublicLocation and managed by Inventory. This behavior may be requested by some other entities for collaboration about the class Part, as described in SEMI T12 for the class Attachment there. This class is stateless as well. Difference of this class from regular Part is that this class may not be so persistent as JiAttachment because physical entity corresponding to this class is a kind of consumable material logically. Some case the material may change container/holder, subdivided, mixed or dumped. Its identification is often assigned with container/holder ID. As long as the uniqueness of identification is guaranteed, the ID may be kept using even if the container/holder is changed.

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