Introduction to the SEMI Standards: GEM300

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1. Overview

Cimetrix created factory connectivity products to help equipment manufacturers comply with SEMI equipment communication standards. The introduction of 300mm wafers created a whole new set of challenges. At Cimetrix, we often receive the following questions:

- Why should I care about the standards for 300mm manufacturing?
- Who or what is SEMI?
- What are the standards about?
- How can we achieve compliance to the standards?
- How do you know when you are compliant?

Continue reading to learn the answers to these important questions.

1.1 Why Should I Care About the Standards for 300mm Manufacturing?

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2. Communication Layers

To provide context for the next discussion, we will use a telephone conversation as an analogy to the SEMI communications standards to help illustrate the different communication layers used in GEM300.

1. Transport Protocol Standards (SECS-I or HSMS) are analogous to the phone system used during the telephone conversation. The transport protocol standardizes how data is transferred between the equipment and the host, including the physical layer.
2. Message Format Standards (SECS-II) are analogous to the language the speakers use in a phone conversation. The message format standards add a layer of organization on top of the transport protocols by defining messages used in the equipment-to-host bi-directional conversation. SECS-II defines a library of messages available for use in other standards.
3. Specific Functionality Standards (GEM/GEM300) are analogous to the subject of a telephone conversation, which provides context for understanding the discussion and the messages transferred between the speakers. For example, you and another person can be speaking in the same language and talking about a sporting event, but if you are both discussing different sports (football versus golf) or different events (the World Cup and the British Open), there will be a significant amount of confusion.

In the GEM300 standards, the specific functionality standards add meaning and interpretation to make use of the data presented by the messages. This is accomplished by describing how and when to use specific SECS-II messages.

3. Transport Protocol Standards

The transport protocol standards define how messages are transferred between the host and equipment. Just as telephone equipment is not responsible for explaining the conversation being held on the call, these transport protocol standards do not define the data contained within a message. The meaning of messages must be determined through some message standard such as SEMI Equipment Communications Standard E5 (SECS-II).

3.1 SEMI E4 SEMI Equipment Communications Standard 1 Message Transport (SECS-I)

The SECS-I standard defines the physical connector, signal levels, data rate, and logical protocols required to exchange messages between the host and equipment over a serial point-to-point data path. This employs an RS-232 communication link. This standard is seldom used today, and is not used at all in GEM300.

3.2 SEMI E37 High-Speed SECS Message Services (HSMS)

The High-Speed SECS Message Services (HSMS) standard defines a TCP/IP-based Ethernet connection. HSMS-SS is the single session implementation of this standard for point-to-point communication between one host and one piece of equipment. It is intended as an alternative to SEMI E4 (SECS-I) for applications in which higher speed communication is needed and the facilitated hardware setup is convenient. HSMS is the transport protocol required in all 300mm fabs.

4. Message Format Standard

This standard defines the messages sent between the host and the equipment, similar to the way a language or idiom defines the words and phrases used during a telephone conversation.

4.1 SEMI E5 SEMI Equipment Communications Standard 2 Message Content (SECS-II).

The SECS-II standard defines the structure of messages. The messages are organized into categories called streams that are identified by an integer between 1 and 127. Each stream category contains specific messages called functions, identified by an integer between 0 and 255. A primary message is odd-numbered function, for example Stream 1 Function 13 or S1F13. A secondary message, the reply to a primary message, is the consecutive even numbered function such as S1F14. For example, a request for data using an S1F3 message would be replied to with an S1F4 message that contains the requested data. In most transmissions when either the host or equipment sends a primary message, the response is the corresponding secondary message. In limited circumstances, there is no reply message. Most of the SECS-II standard is a large library of possible messages, a few of which have redundant functionality. Any specific piece of equipment supports only a subset of the messages defined in the SECS-II standard. In addition, some factories or equipment suppliers define custom SECS-II messages that are not part of the SECS-II standard.

The SECS-II standard also defines a list of data types allowed in messages including ASCII, binary, Boolean, 4- and 8-byte floating points, and both signed and unsigned integers of byte length 1, 2, 4, or 8. A list is also allowed as a container for other data elements, including other lists.

5. Specific Functionality Standards

All of the GEM300 standards depend on the E30 GEM and E39 Object Services standards, so E30 and E39 are always required. All of the other GEM300 standards, with the singular exception of E94, can be used without any other standards, as long as E30 and E39 are implemented. E94 requires E40 in addition to E30 and E39.

5.1 SEMI E30 Generic Model for Communications and Control of Manufacturing Equipment (GEM)

The GEM standard defines when a certain SECS-II messages should be used, in what situations, and what the resulting activity should be. The GEM standard defines a common set of equipment behavior and communications capabilities that provide the functionality and flexibility to support the manufacturing automation programs of semiconductor device manufacturers. Equipment suppliers may provide additional SECS-II functionality not included in GEM as long as the additional functionality does not conflict with any of the behavior or capabilities defined in GEM.

The GEM standard does not attempt to define the behavior of the host computer in the communications link. The host computer may initiate any GEM message scenario at any time, and the equipment must respond as described in the GEM standard. The capabilities described in this standard are specifically designed to be independent of lower-level communications protocols and connection schemes (e.g., SECS-I or HSMS, TCP/IP, HTTP). Use of those protocols is neither required nor precluded by this standard.

The GEM standard defines mechanisms for establishing communication, collecting data, monitoring events on the equipment, report alarms, handling recipes, and several other features. The GEM standard is also very generic, applicable to nearly any manufacturing equipment in any industry. For this reason, the GEM standard is also used in industries outside of the semiconductor manufacturing industry.

5.2 SEMI E39 Object Services Standard: Concepts, Behavior, and Services

One of the changes in methodology in the GEM300 standards from traditional SECS/GEM implementations is the move towards Object Services. The Object Services Standard (OSS) defines a generic data structure known as an object. It provides general terminology, conventions, and notation for describing behavior and data in terms of objects and object attributes. In addition, it provides basic services for reading object attributes, setting their values, and asking for an object's contents in SECS-II Stream 14 messages. This standard is referenced by other standards that define specific objects, which are made accessible through the OSS. Most of the other GEM300 standards define specific types of E39 objects.

5.3 SEMI E40 Standard for Processing Management

Also referred to as the Process Job standard, E40 defines the concepts of material processing, the behavior of the equipment in relation to material processing, and the messaging services that are needed to accomplish material processing. This functionality is grouped into jobs. A Process Job specifies the processing to be applied to the material by a resource. In other words, a Process Job defines which process program (recipe) to use when processing a specified set of substrates (manufactured product, like wafers). A process job may also include parameters to configure the process program. This standard supports individual management of jobs for sequential processing of material within a group and concurrent processing of independent groups. This standard is most commonly implemented in conjunction with E94 Specification for Control Job Management.

5.4 E87 Specification for Carrier Management (CMS)

"E87 standardizes the coordination, execution, and completion of automated and manual carrier transfers to and from the equipment and, if it exists, its internal buffer space." [SEMI E87, 1] It provides the tools to ensure that the desired carriers arrive at the proper equipment for processing and buffers for storage. E87 includes provisions for reserving a specific load port, verifying carrier IDs, and even verifying slot maps (carrier contents) using some Stream 3 and normal GEM SECS-II messages. Until a carrier ID and slot map are verified, the carrier contents may not be processed. E87 provides for tracking carriers at a load port and within internal

buffers, as well as for tracking the status of the carriers, load ports, and carrier buffers. For example, a load port may be "in-service" or "out-of- service." A load port may be configured for automatic AMHS operation or manual loading.

5.5 SEMI E90 Specification for Substrate Tracking

E90 defines a standard means for tracking substrates (manufactured product) in manufacturing in the same manner as E87 does for carriers. It "defines the concepts and behaviors for the management of substrates, as well as the message services… The standard is applicable to any manufacturing equipment that handles substrates." [SEMI E90, 1] In general, E90 provides a method to allow the tracking of wafers through individual components of production equipment. This is accomplished by managing substrate objects and all possible substrate locations within the equipment. More recently, E90 was enhanced to allow the factory to confirm the ID of each substrate before it is processed.

5.6 SEMI E94 Specification for Control Job Management

This specification describes equipment-provided services that support a high level of factory automation. These services provide capabilities for the host to coordinate processing and disposition of materials on production equipment. A control job defines a unit of work for one or more carriers. The work is further described by a set of one or more process jobs to be applied to the material contained in the carriers. E94 must be used in conjunction with the E40 Standard for Processing Management.

5.7 SEMI E116 Specification for Equipment Performance Tracking (EPT)

E116 specifies "basic equipment performance tracking for production equipment" to "…enable the host computer to track basic equipment performance in an automated and consistent manner without operator or host input." [SEMI E116, 1] Not only can the host track the basic equipment states in a modular manner, but when an equipment is blocked from performing a task, the reason is reported to the host.

5.8 SEMI E148 Specification for Time Synchronization and Definition of the TS-Clock Object

E148 provides a method for implementing time synchronization on factory equipment and defines the associated TS- Clock Object. Applying the correct timestamp is key to interpreting high quality data. This helps ensure that the clocks on all the equipment in the factory are synchronized, providing a meaningful reference when reviewing collected data and events. E148 makes use of the Network Time Protocol (NTP) standard, a general protocol already adopted worldwide in the computer industry for computer-to-computer time synchronization.

5.9 SEMI E157 Specification for Module Process Tracking (MPT)

E157 defines standard equipment capability to report process-related data to the factory control system. It focuses on the activities of processing locations (i.e., process modules) that are related to the execution of a recipe. Processing is broken down into steps and reported to the factory during execution. The collection of process data during recipe execution is important to today's semiconductor factories to support various applications that help optimize equipment processes, finished product quality, yield, and overall factory performance.

6. How Can We Achieve Compliance to the Standards?

In order to comply with the GEM300 standards, you must provide the following with your equipment:

1. Hardware and software to implement the SECS-I or HSMS-SS standard as the Transport Protocol
2. Software to implement the Message Format Standard, SECS-II
3. Software to implement each of the required Specific Functional Standards, including the SECS-II message parsing and formatting, state machine management, data publication, and standard interdependencies
4. Software to integrate these standards into the equipment control system

With that in mind, companies can take different paths to achieve compliance with the GEM300 standard. First, you should consider whether you want to implement the standard in-house, or contract with a third party for a turnkey integration. Then, if you decide you want to implement the standards internally, you need to decide if you want to use a software development kit or generate the standards completely internally. Let us look at both alternatives.

6.1 Internal Development vs. Third Party Turnkey Integration

You can decide to implement the GEM300 standards internally, or you can partner with another company that will provide a turnkey integration. In either case, knowledge and familiarity with the current version of the standards is important. Implementing the standards internally will offer your company greater understanding of the standards, but you will need to maintain engineering resources for the effort. This includes not only developing the initial implementation, but also the ongoing maintenance to ensure compliance with new versions of the standards as they are approved. It is important to note that some IC manufacturers have reported problems and frustrations with implementations that were developed in-house by the equipment suppliers. Equipment will not be accepted for production until it passes the tests that verify SEMI standards compliance. The first impression during this testing is very important.

If you are interested in using a third-party supplier, you should know that most companies find a major value in partnering with a company that actively maintains expertise in SEMI standard implementations and provides software and services for implementation of the standards. This helps with interpreting and negotiating requirements with the IC manufacturers, and allows you to draw upon their experience. This will also dramatically reduce risk and deployment time. An experienced third party will avoid the common pitfalls and issues that an inexperienced user would face when implementing these standards. To reduce the risk of being continually reliant upon the third party that develops the implementation, source code should be provided as part of the project deliverables. This will allow you to make minor changes to account for future changes in the standards without having to contract with the third-party company.

6.2 Custom Solution vs. Development Kits

The other decision is whether to use a software development kit (SDK) or to implement the standards without such a foundation. The advantage of a custom implementation is that your company does not have the initial cost of the development kit or any future licenses. However, the risk in this approach is that you will probably need to invest heavily in learning the details of the standards, and that effort is often not part of a company's core competency. There is also significant schedule risk in taking this path.

On the other hand, SDKs offer a more rapid integration of a GEM/GEM300-compliant communications interface. Generally, a development kit does not require a wide breadth of understanding of the SEMI 300mm standards. This radically shortens the

learning curve required to actually start the development of the GEM/GEM300 interface. This decreased time requirement more than offsets the cost of the SDK.

Third-party interface software product companies ensure their SDKs stay current with the constantly changing standards and, when possible, provide hooks to allow support of previous versions. This eliminates the need to send your developers to SEMI meetings, while keeping you compatible with factory host systems. You generally can call upon the SDK provider to keep your engineers aware of changes in the SEMI standards that may affect their project. The SDK should be designed to allow for easy integration of software upgrades related to changes in the SEMI standards. This should hold true for either new development projects or upgrades to equipment that have already been delivered to the IC manufacturer.

An indicator of the SDK provider's success in complying with the SEMI standards AND meeting IC manufacturer's requirements is the number of IC manufacturers' facilities using equipment communications interfaces created with the kit. Since all IC manufacturers have different needs, you should expect your SDK provider to have a presence in most major IC manufacturing facilities. This will help ensure that your software will be accepted at more than one location, and that you are truly receiving the benefit of the SDK provider's experience.

It is important to remember that within the standards there is some room for interpretation. Different IC manufacturers may use the standards in different ways. If you choose a custom solution, it is imperative that your internal developers gain a good understanding of how the software works so that it can be maintained. Custom software rarely satisfies multiple, differing interpretations. At some point, you will be asked to make a change for a specific IC manufacturer. In many cases, SDKs already support the different interpretations, and have configuration settings to enable or disable the desired functionality.

7. Cimetrix GEM300 Solution

Cimetrix delivers a full family of products to design equipment interface applications that will comply with the SEMI GEM300 standards. Cimetrix CIM300™, an off-the-shelf software development kit, guides your engineers (internal and/or contract) to success with your customers. The CIM300 toolkit includes the Cimetrix CIMConnect toolkit to implement SEMI standards E4, E5, E30, and E37. It also includes Cimetrix EquipmentTest™, which is a quick and easy graphical user interface tool for testing the SECS/GEM interface, and SECSConnect™, which can be used to develop more complex testing scenarios.

Cimetrix products were created *by* software developers *for* software developers. Our documentation, training, and passionate support make our products easy for engineers to use.

If the need arises, a global network of Cimetrix Partners can offer complete Professional Services, including turnkey solutions, to assist in your development efforts. We have many customers who have been successful with our SDKs by doing their own integration, using independent contract integrators, or by using the Cimetrix Partner services.

Cimetrix has an outstanding reputation for the products, services, and support we provide to all of our customers. We have many customers who have completed integration and had their tools accepted by all the leading 300mm fabs. We invite you to talk with them, as they will attest to the quality of our products and support.

To get started, we suggest your engineering team review our software, including our sample applications. You will get a clear understanding of our technology, what our products actually implement for you, and the right information to make an informed decision on implementation time and resources.

For more information concerning how to start your own 300mm project, Cimetrix products, SEMI, or how you can get involved in the standards, please contact sales@cimetrix.com.

8. References

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