Transition to Next Generation Logistic Information Systems

The Information Integrated Enterprise

Frauenhoffer F., Sturm R., Kaufmann T., Dorner J.;
Fraunhofer Institute Manufacturing Engineering and
Automation (FhG-IPA), Stuttgart, Germany
Nobelstrasse 12, D-70569 Stuttgart, Tel.: +49(0)711/970-1151,
Fax: +49(0)711/970-1007, e-mail: frf@ipa.fhg.de

Abstract

Within the last 15 years many semiconductor enterprises introduced CIM concepts successfully. The main effort thereby was spent on the development and introduction of Manufacturing Execution Systems (MES), also known as Computer Aided Manufacturing Systems (CAM) or Shop Floor Control Systems (SFC). These systems define the functions to control the activities on the shop floor, including direct control of production equipment management of materials, tools, fixtures and maintenance. Meanwhile several configurable standard systems do exist (e.g. Workstream, Factory Works, Promis, Poseidon), are installed and running within various semiconductor factories around the world.

During the last few years it shows more and more that the focus has shifted from the factory level to the enterprise level. This is mainly due to the increasing global presence of the companies. Since semiconductor enterprises act more and more in a global manner and logistic processes for manufacturing and development span around the whole world, information systems and related architectures have to be developed to cover the new requirements resulting from this focus shift. Semiconductor enterprises of the next two decades will be the testing areas of the concepts of the future. The efficient processing and distribution of logistic information will play a key role in obtaining semiconductor enterprises with a significant higher degree of flexibility, productivity and quality.

Of particular interest is the configuration of the logistic data processing and distribution activities. Information systems of the future used for planning, scheduling and control will execute highly complex algorithms (e.g. parameterized feed forward control) and have distributed object oriented system architectures which can be connected by standard communication interfaces. This paper depicts the problems of providing the proper information technology needed for future

semiconductor enterprises. In addition the presentation will give concepts for approaches to perform the transition to next generation logistic information systems. At the end of these developments will be the Information Integrated Enterprise where

- logistic processes can be effectively planned and controlled
- information system complexity is dramatically reduced
- implementation and support costs are lowered
- enterprise resource effectiveness is increased by the integration of logistics, automation, scheduling and maintenance systems.

Keywords

Computer Integrated Manufacturing (CIM), Information Technology, Manufacturing Execution Systems (MES), Logistic Information Systems, Semiconductor Manufacturing, Computer Integrated Enterprise

1. INTRODUCTION

The power of the installed information systems is mission-critical for the success of any enterprise. The need for improved enterprise wide information systems can be scrutinized especially in semiconductor industry. The demands being made to these systems are raising. The shift to complex products, the need for higher flexibility and the global production networks leads to enterprise-wide logistic processes which are increasingly sophisticated. These forces are among those driving the demand for integrated enterprise-wide information systems to be further integrated and even more efficient than nowadays available systems. Trends depicted in this paper are observed in nowadays semiconductor industry. However, within other industries the necessity for more efficient information systems is likewise expected.

2. TRENDS IN SEMICONDUCTOR INDUSTRY AND THE NEED FOR IMPROVED ENTERPRISE WIDE INFORMATION SYSTEMS

In 1996 a total revenue of 144 billion US\$ was achieved in the semiconductor manufacturing market /BAL97/. In the following years the revenues reached within this business are further growing at a rapid rate. One of the main driving forces is the increasing demand for ICs. IC devices build the core technology many other high end products rely on: multimedia PCs, complex automotive applications and cellular phones are just examples therefore.

Trends in Semiconductor Manufacturing

According to SEMATECH the industry has the goal to reduce the cost per chip function from 25% to 30% each year /BAL97/. This is necessary to retain competitiveness within this highly aggressive market. Reducing feature sizes, increasing wafer sizes, maximization of yields and improving equipment productivity all contribute to this goal. In future the improvement of equipment

productivity will play an even bigger role since larger wafer sizes and improved yields are expected to have a decreasing impact. Apart from the optimization of these "manufacturing performance parameters" of single fabs, the improvement of "enterprise performance parameters" will play a major role. Shorter time-to-market, higher scheduling stability, higher number of products and product developments, and of course minimized costs together with top quality are essential.

A successful semiconductor manufacturer has to accommodate to a lot of complex and also sometimes opposed and contradictory requirements to fulfil the customer demands as well as to ensure the own profitability. These can be summarized as follows.

- Delivery of products with the best benefits for the customer at the lowest possible costs retaining high quality
- Assurance of a high scheduling stability
- Short delivery cycle
- Minimized time-to-market and short development times
- High flexibility according to customer demands (functionality, order quantities and delivery dates)

The prospect around the year 2000 will probably be as follows /INO95/:

- Devices in terms of 64MDRAM, 256MDRAM will be produced in high volume fabs
- 1 GDRAM will be in the first stage of production
- 300mm wafers are introduced and in serial production

Under these circumstances the role of Logistic IT Systems (Logistic Information Systems) will become increasingly important to deal with the resulting requirements especially those from the world wide logistic production chains.

Increased Number of Customers and Products

Future semiconductor enterprises have to attend to the needs of a wide range of customers of different market segments such as automotive, telecommunications, etc. This ensures the long term success of the enterprise at the rapidly changing market independent of the well being of single market segments. An important prerequisite therefore is, that the semiconductor manufacturer can deliver within a wide range of customer fields at the same time. This in general leads to a high number of products and product variants. E.g. for future integrated circuit products the number of product variants for a single product can range from a few dozens to several hundreds. A total of over 2.000 products in an ASIC fab which are active at the same time will be usual. It is obvious that all tasks related to the development, the production and the delivery of these products have to be handled efficiently by IT Systems. Furthermore, an effective mechanism for variant and version handling has to be provided in order to keep track of the changing data.

Enterprise Wide Scheduling

Fab cycle time is a function of raw process time, internal disturbances and waiting times of each production phase. Enterprise cycle time in turn is related to the various fab cycle times of the production phases as well as to inter area delay times at the transition from one production phase to the next.

A production plant is dimensioned and built for a certain capacity. For instance, a waferfabs' capacity is generally expressed by the number of wafer starts per week (WSW). The behaviour of the production side and its productivity is commonly measured by the average cycle time for a specific product in reference to WSW and throughput. Especially for make-to-delivery production such as ASIC, the fab cycle time varies with the permanently changing product mix and production order release. Hence, the planning process and the assurance of delivery dates is difficult to achieve. However, the prediction and estimation (forecast) of cycle times for certain customer orders is essential to meet delivery dates.

Therefore, the cycle time for specific products should be predictable and the cycle time variance has to be kept as small as possible independently of the variance of the product mix. Moreover, the enterprise cycle time has to be reduced dramatically in order to remain competitive in the semiconductor market. Potential reduction can be seen at the transition between the various production phases. For instance, delay times after the waferfab and prior to the release into the test area can be reduced significantly by an effective enterprise wide scheduling process.

As a result the production phases have to be synchronized by higher integrated information systems. The production order release into the plant should also be performed with feed forward to following production areas or locations. This requires an effective, permanently updated scheduling and dispatching process which has to involve the entire enterprise.

World Wide Production Network

The IC manufacturing process is performed in the production phases wafer fabrication, wafer testing, assembly and final testing. These phases are generally distributed across several production plants and sometimes stretch across a couple of different enterprises. Each production phase is important for the final product such as an tested device. Consequently, it is necessary to plan and optimize across the whole production network. The target is to find an optimum way through the network for the fulfilment of a given order with highest efficiency (effort/costs). In current global logistic chains more time is lost due to transport and waiting times than for actual processing and manufacturing.

Figure 2 depicts in a simplified manner the material and information flow of an IC from the order entry of the customer to the delivery to the customer. Various ways and alternatives through the network do exist thereby. In reality the logistic chain is far more complex. Therefore, the number of processes and interfaces for material and information flow are extremely high and difficult to manage.

Fig. 1 World Wide Production Network

Especially the distributed order management (planning, executing and controlling of orders) in world wide semiconductor production networks is not supported in an adequate way by current IT Systems within the semiconductor manufacturing industry. Future systems have to be more communicative than the systems used today. IT Systems of the next generation must also include functions to effectively plan and coordinate order planning, execution and controlling activities across several distributed plants and enterprises. It is also beneficial to provide a higher involvement of customers and the supply chain industry within the IT network. Common data models for orders, product specifications and quality data are necessary for easy interfacing.

Enhanced Flexibility to Environmental Change

As mentioned above, existing semiconductor production facilities are designed for a specific product range and a predefined capacity. A slight change within the product palette or the order quantities might impact tremendously to the cost efficiency and the performance of the enterprise. Consequently, an increasing flexibility is needed to manage strong alternating order scenarios as well as increasingly aggressive customer demands without raising the manufacturing cost. Accordingly, flexible solutions have to be realized beginning with the process steps at certain equipments up to the plant wide material flow and the logistic chain of the whole enterprise. For this the material flow controlling concept of the IT System has to be modular and extensible.

Time to Market, R&D Expenditure, Yield Improvement

For marketing the new and advanced semiconductor devices like 256MDRAM and 1GDRAM, shorter lead time from the design cycle, process development and mass production ramp up is the key for competitiveness. Typical values for time-to-

market within the IC industry nowadays varies between 18 and 36 months. Target is to go down to 9-15 month (product dependent).

In future the development stage is expected to be more complicated than today's. Similar to the production process, the development process will also be world wide distributed. At the moment contribution of IT Systems is largely focusing on mass production and automation. To realise the minimum time to market, however, the IT System is required to solve a different domain. That is, how to speed up the design and process development cycle as well as the integration of development cycle and mass production.

Achieving higher yield ramp-up for future devices seems to be more and more difficult for future products because of their increasing complexity. To shorten the development cycle the intensive sharing of data between trial production and mass production is necessary. As well the provision of actual production data to support development and design is very important. This way know-how which comes from production can be incorporated in design very early.

First Silicon Right and yield are important metrics which are fundamental for the conversion of new developments in a serial product. Lots of effort has to be done to maximize yield for new technologies and products. Yield crashes may also concern serial products. Typically in actual fabs a yield crash is not detected until wafer or final testing. Thus a lot of time passes between actual occurrence and detection of the yield crash. Yield crashes may cost a factory depending on the fab capacity and the kind of crash from a few hundred thousand dollars up to ten million dollars and more with recovery times from one day to several weeks /ATH96/. Therefore a future requirement for IT Systems is to detect and localize yield crashes as early as possible and recover it.

Increasing Complexity of Process Flows and Products

Process flows within semiconductor manufacturing are getting more and more complex. Typical process flows for wafer fabrication can consist of 500 and more individual process steps which have to be performed within an exact sequence and time frame. Estimates for future 300mm technology consider up to 2000 individual steps per IC product. In addition to the process flow specifications a lot of additional data has to be provided including quality specifications, test informations and process simulation results. Consequently, future product and process specification systems have to provide means to maintain the huge amount of data and documents which are necessary to specify and release the process specifications.

Potential Benefits of Next Generation Logistic Information Systems in Semiconductor Enterprises

The automation of complex logistic processes across the whole enterprise is a major challenge for all semiconductor manufacturing enterprises: all important business processes, which are very often distributed across several locations, have

to be planned and controlled effectively. The means to do this are modern information systems and related architectures. All relevant data of the enterprise is kept within these systems and logistic processes run on them. A study of the Fraunhofer IPA has given the benefits reachable by the introduction of highly flexible next generation Logistic IT Systems within semiconductor enterprises (Figure 2).

Fig. 2 Benefits of Highly Flexible Logistic Information Systems

Fab cycle time and inventory cost reduction requires for effective plant wide scheduling systems, production order release strategies based on real time information of plant status. The shorter time-to-market, R&D cost reduction as well as the increase and faster development of new products can be achieved by fast feed back information of manufacturing data to R&D and planning departments. The higher flexibility with respect to order sizes and production range at the same cost level demands for scaleable plants and production sides. Therefore the fast linkage to suppliers and subcontractors as participants in the logistic production network is an important issue. Moreover the exchangeability of network participants and the permanent reconfiguration process of the enterprise has to be supported by next generation IT systems.

3. REQUIRMENTS FOR FUTURE LOGISTIC IT SYSTEMS

As it was shown in the preceding paragraphs, the design and fabrication of state-of-the-art semiconductor devices and integrated circuits is getting increasingly complex. Strong business drivers force the further development of information technology to support the complex logistic processes. The goal of future logistic information systems is to support enterprise wide development and manufacturing processes in a more integrated way by better fulfilling the depicted requirements. In the following some of the most important requirements for future Logistic IT Systems are described (figure 3).

Fig. 3 Requirements for Future Logistic IT Systems

Enterprise-wide IT Systems and Communication Network

To support the world-wide production chain of a semiconductor enterprise it is a necessary requirement for future Logistic IT Systems and related communication networks to include all relevant development and production sites of the corporation,. Moreover the production sites of material suppliers and subcontractors also have to be integrated.

Therefore a communication technology has to be provided by which different IT Systems of different locations can be interconnected across the whole world. A major problem having to be solved for future communication networks is the provision of high bandwidth. To support distributed development and production planning huge and even growing amounts of data will have to be transferred.

IT supported Business Processes

The trend is to obtain a tight relationship between the company's business processes and its information systems. The design and evolution of the systems should stem from the corporate strategy. More and more important in this sense is the IT support of enterprise wide business processes. Having the opportunity to

plan and control business processes using powerful interconnected IT Systems, critical parameters within production and development can be more thoroughly tracked and optimized. The improvement of enterprise wide cycle times and the reduction of time-to-market can probably be boosted by having access to the actual status of the different resources related to the business processes. This also incites companies to formalise their business processes in order to have a better knowledge of them. Thereby they have additional possibilities to improve the processes e.g. using new methods like business process simulation and optimization.

Distributed Planning and Control Algorithms

Within future Logistic IT Systems complex distributed planning and control algorithms will be employed. One of the most important tasks thereby is to improve the information flow between the different sites of the enterprise and to the material suppliers and subcontractors. In addition the better integration of development and production areas is necessary. E.g. quality measurement data from prototype manufacturing should be fed back to development, so corresponding process specifications can be optimized as early as possible.

Rich Data Management

In future various kinds of data have to be managed including existing record-based data, documents and unstructured data. This includes active multimedia compound documents that can be moved, stored, viewed and edited in-place anywhere within the IT System. The system should provide compound document technology for example OLE or OpenDoc for doing mobile document management. Of course, this environment must also support existing record-based data structures including SQL databases.

The amounts of data which have to be managed by future IT Systems will be very high and rapidly growing. Database sizes containing giga- to terrabytes of data of different kinds have to be handled effectively. The proper database technology has to be provided therefore.

Integrateable, flexible and scaleable IT Architectures

Concerning the IT Systems, future IT Systems must be integrateable among themselves. This means they have to provide a modular structure consisting of independent units which can be connected to each other in an easy and standardized way. Since the functionality of existing applications is seldom sufficient, the architecture must be flexible enough to accommodate the evolution and growth of the product suite. New systems must be able to support a wide range of enterprise sizes. Therefore it must be possible to add clients and servers without reducing system performance.

4. TRANSITION TO FUTURE LOGISTIC IT SYSTEMS

The major contributions to future Logistic IT Systems have now been reviewed, but what characteristics will future systems have and how can problems of developing and integrating them be minimized?

Business objectives drive the software development and integration process. The goal is to simplify the process and reduce the costs of integration. It's valuable to stay focused on the big picture, the total information needs of the enterprise, not just a single site or area. There have to be met the requirements of the enterprise managers whose focus is on improved performance, shorter cycle-times, shorter time-to-market, on-time-delivery and reduced inventory. To meet the needs for an improved decision support of enterprise managers, future IT Systems must stretch across the whole enterprise, support business processes as well as distributed planning and control algorithms. They must provide means to handle rich data and be integrateable among themselves and highly communicative.

These requirements can be met with new IT solutions. Today IT Systems are under development which can be outlined as follows (figure 4):

Fig. 4 Elements for Future Logistic Information Systems

Distributed Computing using distributed Object Technology

Distributed system technologies and networking make it possible to integrate various systems which otherwise function separately, and enable managers and engineers to get total effect on semiconductor development and manufacturing. Characteristics of these systems will be

- Component based architecture, enabling interoperability and exchangeability
- Language and operating system independent
- Client/server computing, which provides flexible means to decouple functionality and use distributed processing power more effectively
- N-tier in place of a rigid 3-tier client/server design, with dynamic distribution of application functionality as needed
- Internet-based communication, replacing enterprise proprietary systems
- HTML based graphical user interfaces, providing a thorough familiar interface

- Conformance to communication and infrastructure standards e.g. using standardized middleware like OMG's CORBA /OMG98a/
- Configurable application which can be customized by non-programmers
- Domain engineered for virtual enterprises

The distributed environment must provide the semblance of a single system image across potentially thousands of client/server machines. The physical storage place of the information is irrelevant thereby. Users and programs should be able to dynamically join and leave the network, and then discover each other.

It must be guaranteed that accesses and changes to existing distributed data is consistent. Therefore rich transaction capabilities supported by large object-oriented databases will be needed. In addition to support the venerable flat transaction, the new systems must be able to handle nested transactions across multiple servers, long-lived transaction that execute over long periods and queued transactions that can be used in secure business-to-business dealings.

Global Semiconductor and Information Technology Standards

Industry-wide standard-based application architectures can decrease integration time and reduce the time and cost of initial IT System start up. To achieve this, future architectures must be open and comply with de jure or de facto standards such as CORBA /OMG98a/ or COM/DCOM /COM95/. Furthermore it should be compatible to domain specific frameworks e.g. from SEMATECH (CIM Framework) /SEMA96/ or OMG (PDM Enabler, MES Enabler) /OMG98b/ which in general define components, their services and behaviour as the element of standardization and substitutability. Standardized services thereby enable the collaboration of independent software components. The business and component object models provide the precision necessary for application integration. They have well defined interoperability interfaces and behaviour including class names, superclasses, description, published events, provided services, raised exceptions, contracted services and subscribed events.

New component based architectures offer the best way to build modular, reusable and distributed applications. Each standardized component has a default configuration, which comprises the base objects and behaviour provided by the system. The base model can be easily extended through inheritance and altered if necessary to meet users needs.

Holistic Software Development and Integration Process

Logistic IT Systems cannot be purchased like a product. Moreover the development and integration of Logistic IT Systems is a continuously evolving complex process, requiring a close relationship between the customer and the different software providers.

In future the process of software development and integration will become holistic in the sense that it will more focus on

- **Integration of corporate strategies with information systems:** obtain a tight relationship between the company's business processes and its IT Systems.
- **Evolution and transition management:** the evolution of information systems and software development has a big impact on the business processes of a semiconductor enterprises. According to /HILL98/ this is not always well accepted or understood, and it is important to manage these changes if they are to be embraced by the workforce.
- **Managing the human factor:** apart from existing information technologies, such as distributed objects and the web, the "human factor" in software development gets more and more important. The use of web-based groupware and CASE tools in software development to coordinate large development teams will be an essential requirement to perform large scale implementation projects. In addition an experienced project management is an essential requirement.

5. CONCLUSION

The emerging trend of the semiconductor industry to reduce the cost per chip function from 25% to 30% each year leads to various paradigm shifts to retain competitive within this highly aggressive market. The significant improvement of "manufacturing performance parameters" and in future even stronger "enterprise performance parameters" will play a major role. Shorter time-to-market, higher scheduling stability, higher number of products and product developments, and of course minimized costs as well as a top quality are essential. Under these circumstances the role of Logistic IT Systems will become increasingly important to deal with the requirements for enabling world wide logistic production chains. Also the automation of complex logistic processes across the whole enterprise will play a key role in future strategic company decisions. A study of the Fraunhofer IPA has shown the benefits reachable by the introduction of highly flexible next generation logistic IT Systems within semiconductor enterprises.

The requirements of new IT solutions can be met enabling distributed computing using object technology with e.g a component based architecture, N-tier client/server design, and conformance to communication and infrastructure standards. Standards for future Logistic IT Systems are under development in various organisations as SEMI or OMG.

The shift to future Logistic IT Systems is an enormous challenge for the semiconductor industry, but beneficial and achievable: a further step towards the information integrated enterprise.

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7 BIOGRAPHY

Frank Fraunhoffer obtained his diploma degree in Electrical Engineering at Stuttgart University, Germany, in 1995. Since 1995 he has been a scientist at the Fraunhofer Society, Institute of Manufacturing Engineering and Automation (IPA) in the Department of Cleanroom Manufacturing. As a project leader he is

responsible for several projects in the area of manufacturing science in microelectronics, cleanroom automation and information technology. His primary working fields are the development of information technology and logistic concepts for semiconductor industry.

Roland Sturm obtained his diploma degree in Production Engineering at the University of Erlangen, Germany, in 1996. He worked as a employee at the Institute of Manufacturing Automation and Production Systems, University of Erlangen in the area of electronics assembly and packaging. Since 1997 he is a scientist at the Fraunhofer Society, Institute of Manufacturing Engineering and Automation (IPA) in the Department of Cleanroom Manufacturing. His working fields are the development of automation and logistic concepts for semiconductor industry. He works in several industrial and research projects in the field of information technology, fab simulation, logistics and material flow.

Thomas Kaufmann obtained his diploma degree in Mechanical Engineering at Stuttgart University, Germany, in 1995. Since 1993 he has been a scientist at the Fraunhofer Society, Institute of Manufacturing Engineering and Automation (IPA) in the Department of Cleanroom Manufacturing. As a section manager he is responsible for the working fields of manufacturing science in microelectronics, cleanroom automation and information technology. Thomas Kaufmann is Task Force leader of the SEMI Europe CIM Framework Task Force and member of the SEMI North America CIM Framework Task Force.

Johann Dorner obtained his diploma degree in Chemical Engineering at Stuttgart University in 1987. Since 1987 he has been a scientist at the Fraunhofer Society, Institute of Manufacturing Engineering and Automation (IPA) and since 1990 he is the head of the Department Cleanroom Manufacturing. He is working with 40 scientists/engineers and 50 assistant scientists in the area of system & equipment development and production optimization. System & equipment development contains tasks like development, construction, optimization and qualification of equipment and components for clean and high precision demands. Work in the area of production optimization are characterized by detection of potentials for cost reduction and implementation of manufacturing automation methods and systems. Johann Dorner is also active in national and international committees especially for the semiconductor industry.