半導體供應網路決策品質促成技術研究(I)-子計畫一

虛擬晶圓廠製造服務提供機制及其促成工具之研究

Manufacturing Service Provisioning Mechanism and Enablers in a Virtual Fab

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主持人：張時中教授

共同主持人：郭瑞祥副教授

計畫參與人員：黃亭凱、謝博偉、林毓廷、張意如。

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一、中文摘要

在競爭激烈的半導體產業，虛擬晶圓廠和製造服務觀念的提出已有數年之久。為了解在動態環境下的虛擬晶圓廠彈性製造服務提供機制之觀念，本計畫從晶圓製造代工廠的角度，清楚的定義結合製造服務的虛擬晶圓廠，並依此提出一個虛擬晶圓廠的促成架構。這個虛擬晶圓廠的促成架構包含三個物件層：製造服務、商務程序和基礎建設層。藉由設計一個動態製造服務提供機制之方法，將介於這三個層次的物件，彈性的結合成各種製造服務。針對彈性服務的考量，這個方法的架構包括：名稱的對應、商務程序組合、資源預約組合和製造服務管理組合。為評量該架構和動態製造服務提供機制的合適性與可行性，本計畫以一個晶圓製造代工廠所提供的訂單承諾服務為研究案例。藉由一個針對訂單承諾服務應用的動態製造服務提供機制之系統設計與實作，顯示出現有的資訊技術、CASE 工具、晶圓廠資訊基礎建設和資料/資訊的可得性，使得動態製造服務提供機制可充分實現，並可適當的被應用在虛擬晶圓廠和電子商務的發展。

關鍵詞：製造服務、虛擬晶圓廠、啟動架構、物件導向技術、動態製造服務提供機制、訂單承諾服務

Abstract

The concepts of virtual fab (VF) and manufacturing service have been proposed by practitioners over the past few years to face the fierce competition of the semiconductor industry. To realize the concept of VF with flexible manufacturing service provisioning in a very dynamic environment, this project, from the standpoints of a foundry fab, clearly defines VF together with manufacturing service, and proposes accordingly a VF enabling framework. The VF enabling framework consists of three layers of objects: manufacturing service, business process, and infrastructure layers. A novel scheme of dynamic manufacturing service provisioning mechanism (DMSPM) is designed to flexibly compose objects among the three layers into various manufacturing services. The skeleton of the scheme includes name mapping, business process binding, resource reservation binding, and manufacturing service management binding for flexible service composition. To assess the feasibility and potential of the framework and DMSPM, the order commitment service (OCS) provided by a foundry fab serves as a study case. A prototype system is designed and implemented to realize DMSPM in the OCS application, which demonstrates that current information technology, CASE tools, fab information infrastructure, and data/information availability make DMSPM readily realizable and that DMSPM has a good potential for application to VF and e-business developments.

Keywords: manufacturing service, virtual fab (VF), enabling framework, object-oriented (OO) technology, dynamic manufacturing service provisioning mechanism (DMSPM), order commitment service (OCS)

二、緣由與目的

The concept of VF is to facilitate intensive interactions between the foundry fabs and their customers, including fabless design houses, system vendors, or IDMs. Fig. 1 depicts four levels of interactions. The interactions are at the minimum level when only existing process technologies and product designs involved, and are the most intensive when new designs of product and process technologies are concurrently developed. To reduce costs of interactions in searching, communications, and monitoring, a new "glue-integration" approach is needed for stitching a foundry fab and his partners together as if they were in a single firm to facilitate seamless relationship between the foundry fab and his customers. How VF should be designed as part of the glue-integration approach is critical to the competitiveness of foundry fabs and has posed significant challenges to their developments.

Flexibility, speed, and transparency of manufacturing service provisioning are three key target effects for a foundry fab to develop its internal VF environment as part of the glue-integration approach. In spite of the attractiveness and significance of VF concepts, the definition and realization approaches for VF remain either ambiguous or diverse to most of the practitioners. The goals of this project are then:

(1) to provide definitions of VF and manufacturing service,

(2) to propose a VF enabling framework as a foundation for flexible and quick provisioning of manufacturing services,

(3) to design a dynamic manufacturing service provisioning mechanism (DMSPM) based on the VF enabling framework, and to assess the feasibility and merits of our designs by using the order commitment service (OCS) as a carrier.

三、結果與討論

I. Definition of Manufacturing Service for Virtual Fab

Fig. 2 depicts the value chain and service delivery model in a service-driven manufacturing firm. As can be seen, *manufacturing service* provisioning includes the delivery of *both tangible and intangible products*. Tangible products are real and touchable entities such as probed wafers or packaged dies. In the traditional foundry fab model, the tangible products represent most of the value delivered to customers. In a manufacturing service-driven VF model, however, they are only the minimum requirements from customers' expectation. Additional intangible products must be created and delivered to customers as part of the manufacturing service. Here we define these *intangible products as customers' involvement in part of manufacturing processes or the value-adding functions from the customers' point of view.* That is, in a VF model, the tightly coupled, concurrent interactions between the manufacturers and the customers create new manufacturing service to the customers. With this definition in mind, we then provide several examples of manufacturing service for a VF in Table 1.

II. Virtual Fab Enabling Framework

The VF enabling framework is an object-oriented (OO) technology based framework to provide control and management of manufacturing services over an object-oriented (OO) fab model. Fig. 3 shows the proposed three-layered framework that consists of manufacturing service (MS) layer, business process (BP) layer, and infrastructure (IR) layer. The three layers work together on a manufacturing service provisioning but with different specialization. From customers' standpoints, MS layer works as an interface to establish the customer request while BP and IR layers work together to implement the request. That is, the interface establishes what requests a customer can make for a particular object in MS layer. To satisfy that request, the associated objects in the BP layer may link objects in the IR layer to carry out such request.

In this framework, objects with different abstraction in a fab are distributed among the three layers. The object in a higher layer can reuse objects in its adjacent lower layer. Flexibility is then built in this framework. The degree of flexibility, however, is quite different in each layer. The higher a layer is, the more changeable an object in this layer is. The generic principle of how the three layers cooperate to provide manufacturing services to customers is depicted in Fig. 4. Conceptually, each layer consists of two roles of objects: operator and manager. The operator-objects carry out the provision of manufacturing services while the manager-objects perform either administration or coordination job. Administration job involves the supervision of operator-objects' performance in order to guarantee the quality of manufacturing services within its own layer. Coordination job involves the coordination of manager-objects across different layers in order to make sure that objects in three layers work together properly. By separating the roles of operators and managers, better consistency of defining and flexibility of binding objects are achieved [4].

This project designs a control mechanism, called a dynamic manufacturing service provisioning mechanism (DMSPM), to enable the cooperation of objects with different roles among three layers in the VF enabling framework (Fig. 3). The key concept of DMSPM is object binding [5], [10].

III. Dynamic Manufacturing Service Provisioning Mechanism (DMSPM)

DMSPM is a control mechanism designed to enable the cooperation of objects among the three layers in the VF enabling framework to flexibly provide manufacturing services. It can bind or configure a set of objects modeling the entities or states in a fab into manufacturing services in a very flexible way. Inputs of DMSPM are manufacturing service requirements from customers and its outputs are the managed manufacturing services. According to the associating and activating concept of object binding, the process of manufacturing service provisioning in DMSPM can be broken into two phases in sequence: creation and execution. First, creation phase plans or designs how a requested manufacturing service should be fulfilled. Second, execution phase carries out the manufacturing service fulfillment plan in the way that has been created.

As shown in Fig. 5, a skeleton of the DMSPM is extracted from the procedural commonality of the two phases. There are four steps in the skeleton: name mapping, business process binding, resource reservation binding, and manufacturing service management binding.

Fig. 6 illustrates how DMSPM is applied in a VF enabling framework, i.e., how the skeleton steps just described bind objects of individual layers into a manufacturing service. In this figure, an arrow represents the direction of interaction while the associated numbering represents the procedural sequence of DMSPM. For example, a customer requests manufacturing service via the interface object in the MS layer. After name mapping by such an interface object, DMSPM further binds BP objects in the BP layer accordingly to generate workflow for the manufacturing service. DMSPM then binds resources in IR layer to each BP object so on and so forth.

How may the DMSPM be enabled by available technologies? Commercial Object-Relational DBMS products [13] are available to store all the objects of fab model together with their relationship and behavior in a database. The binding actions or the dynamic linkage can be implemented via object oriented programming [5] and the corresponding CASE tool [11]. Moreover, the techniques of run-anywhere web and one-to-one tool [2] are well developed for manufacturing service interface. The techniques of bill of material (BOM) [9], customized interpreter, standardized data exchange, and name translator [6] is implemented to fulfill name mapping. Using an in house developed or a commercial scheduling/planning tool can perform the resource reservation binding. For example, commercial software such as ERP system [8] can be used to perform production plan or scheduling to calculate resource quantity and time to be reserved for quality of service provisioning. Finally, project management [1] function is included in the manufacturing service to monitor service, quality, cost, and time to fulfill manufacturing services management binding and then to complete the DMSPM.

IV. Realizing DMSPM in Order Commitment Service

To convey the ideas and to assess the practicality of DMSPM under the VF enabling framework, we adopt a simplified order commitment service (OCS) as our case study [3]. Fig. 7 depicts an abstract workflow of OCS, which is extracted from the practices of two leading foundry service providers, TSMC and UMC Group, and is also locally called the available-to-promise (ATP) service. As shown in Fig. 7, after receiving customers' orders, sales department sets priority to each order jointly with the production-planning (PP) department. Based on this priority and ordered quantity of an order, PP makes a wafer output plan for the order by calculating capacity requirements of the order, checking residual capacity of fabs under the on-going production schedule, allocating the available capacity and scheduling resource reservation and the due date. The workflow finally confirms the due date with individual customers to complete OCS procedures. A good OCS must quickly provide customers with credible and short cycle-timed delivery schedules and transparent OCS business processes.

Fig. 9 illustrates the overall flow of how DMSPM composes an OCS under the VF enabling framework. As mentioned, objects of each layer have either of the two roles: operator or manager. In Fig. 8, un-shadowed objects are operator-objects while the shadowed ones are manager-objects. For conciseness of expression without sacrificing the key concepts, we aggregate objects in each layer into a representative manager-object and a representative operator-object in Fig. 9 to illustrate the application of DMSPM to OCS. The representative objects can further be blown out for interactions among detailed objects. For example, Fig. 10 also illustrates detailed flows and interactions within a BP-operator object.

By utilizing the sequence diagram of UML, Fig. 9 indicates the DMSPM step sequences of creation and execution phases for OCS provisioning. In the creation phase, a customer object requests an OCS by sending messages of order specification to a user-interface object in the MS layer. The user-interface object then conducts name mapping and sends internal service requirements to the OCS-MS object in the MS layer. This OCS-MS object links the necessary BP layer objects. As part of their functions, individual BP objects then link necessary resource objects and reserve them in the infrastructure layer. An OCS plan is thus formed. Manager-objects in each layer are then successively linked to this OCS plan from the bottom layer to the top layer to form a managed OCS plan. A manager-object can be a piece of computer software or a human decision-maker in real applications. This managed OCS plan is carried out in the execution phase. During execution, objects in each layer follow similar steps as the creation phase but actually carry out the service functions to fulfill this managed OCS plan and deliver a managed OCS to customers.

To realize DMSPM in the OCS application, a prototype system is designed and implemented [3]. Fig. 11 depicts the system architecture, where the DMSPM server is the focal point. Rational ROSE is adopted as our CASE tool for both OO modeling of OCS in terms of UML [12] and C++ code skeleton generation [11]. The DMSPM server is coded in C++ while the browser and the web server are in Java. The DMSPM server implements the common steps of DMSPM skeleton for creation and execution phases for OCS provisioning. Although the manager-objects are C++ codes in the prototype, they can be human decision-makers in real application.

In our prototype development, it is found that input data and/or information to DMSPM are mostly available from the information system of a fab and its company. Most business process documents are available in a company passing ISO 9000 verification except that they may need to be computerized. The inputs to OCS at least include order quantity, product type, technology, and expected due date while the outputs include the committed due date and the wafer out plan. Our experimentation results demonstrate both the ideas and the potential of DMSPM for application to virtual fab and e-business developments.

四、計畫成果自評

This project clearly defines, from the standpoints of a foundry fab, VF concept together with manufacturing service, and proposes accordingly a three-layered VF enabling framework. A novel scheme of dynamic manufacturing service provisioning mechanism (DMSPM) is designed to flexibly compose objects among the three layers into various manufacturing services. Feasibility and potential assessment via the case study of order commitment service (OCS) demonstrates that current information technology, CASE tools, fab information infrastructure, and data/information availability are ready for realizing our design. These results accomplish the first five tasks in our proposal. Tasks 6 and 7 of the original proposal were not conducted because the granted budget is only 55% of the original proposal. We have submitted a paper to IEEE Transaction on Engineering Management based on the above results.

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Interaction Pattern / Product Type	Technology-related service	Production logistics-related service
Intangible product	• IP Library usage • Technology catalog • Advanced technology • Qualification • Wafer acceptance test data access • Yield data access • Failure analysis and report	• Capacity reservation • Due-date quote • Order status checking • On-time delivery • Exception handling • Quick response • Turnkey service
Tangible product	• Wafer • Probed wafers • Packaged dies	

Table 1: Types of manufacturing services for a virtual fab

		Product Design: Existing	Product Design: New
Process Design	New	intensive	most intensive
	Existing	minimum	medium

Fig. 1 Interactions between product and process development

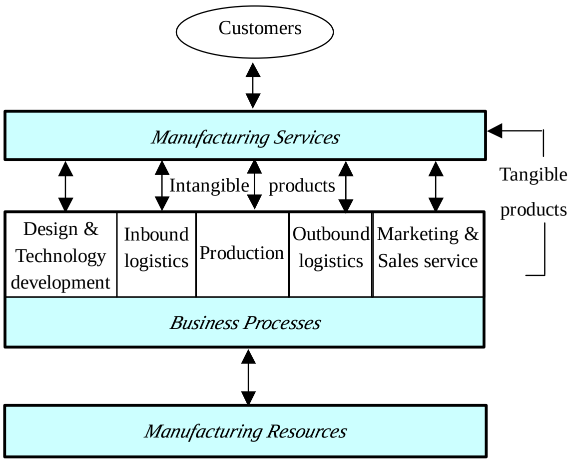

Fig. 2 Value chain and service delivery model

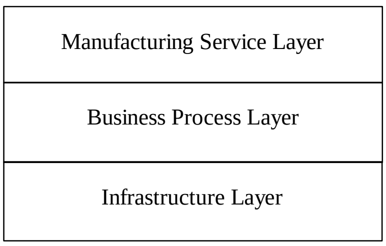

Fig. 3 Three-layered VF enabling framework

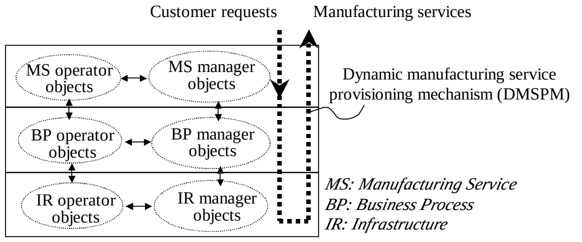

Fig. 4 Cooperation of three layers for manufacturing services provisioning

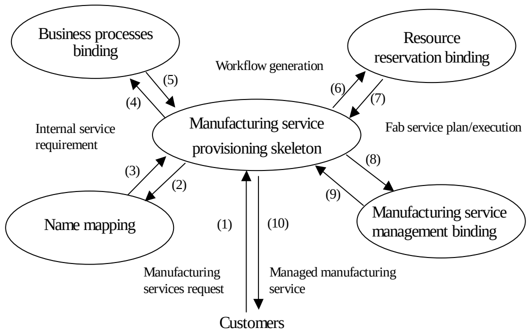

Fig. 5 Manufacturing service provisioning skeleton

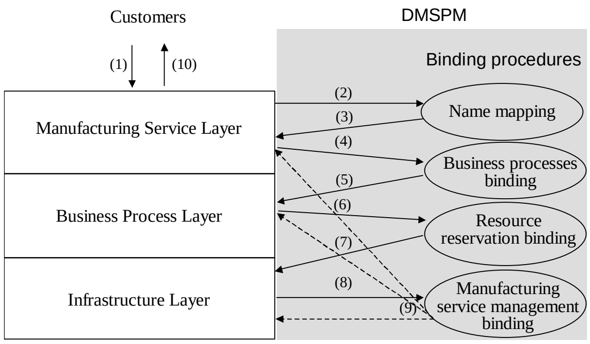

Fig. 6 Application of DMSPM in VF enabling framework

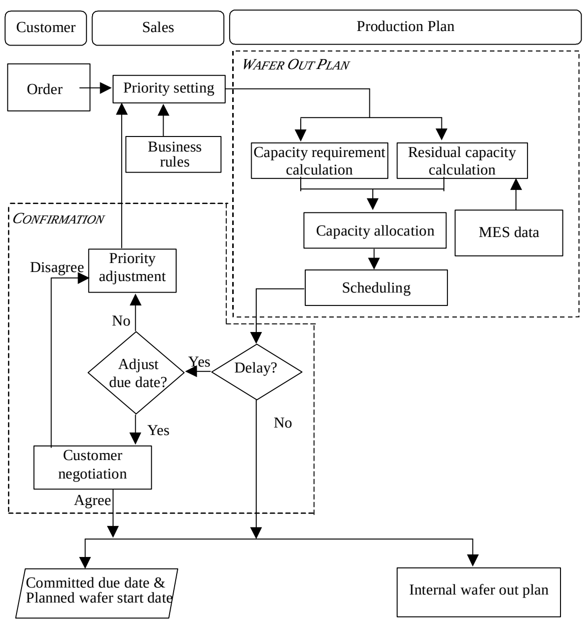

Fig. 7 Order commitment service workflow

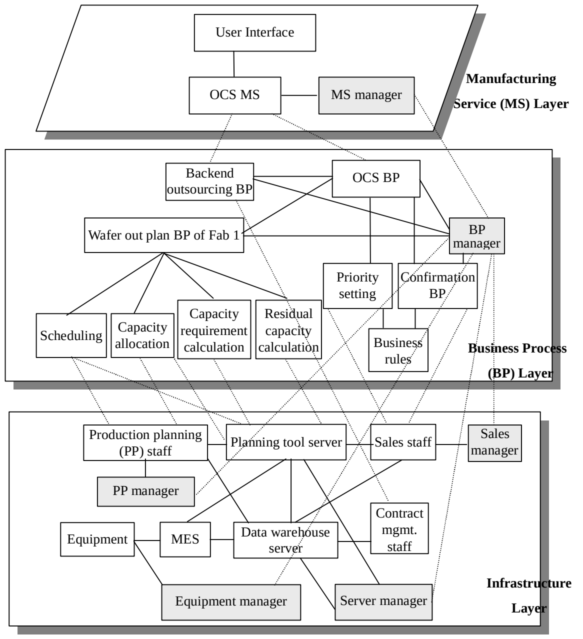

Fig. 8 Relationships among objects for OCS provisioning

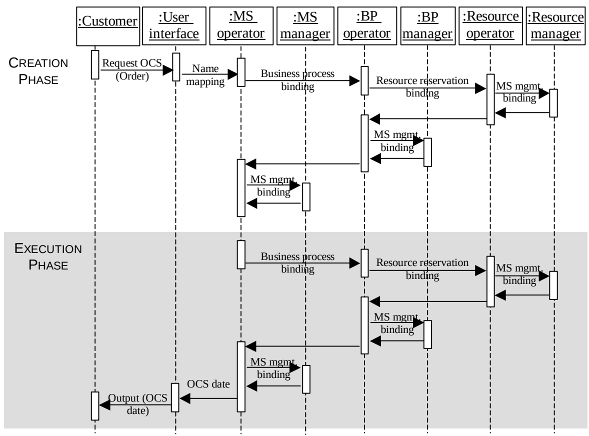

Fig. 9 Sequences diagram of DMSPM in OCS provisioning

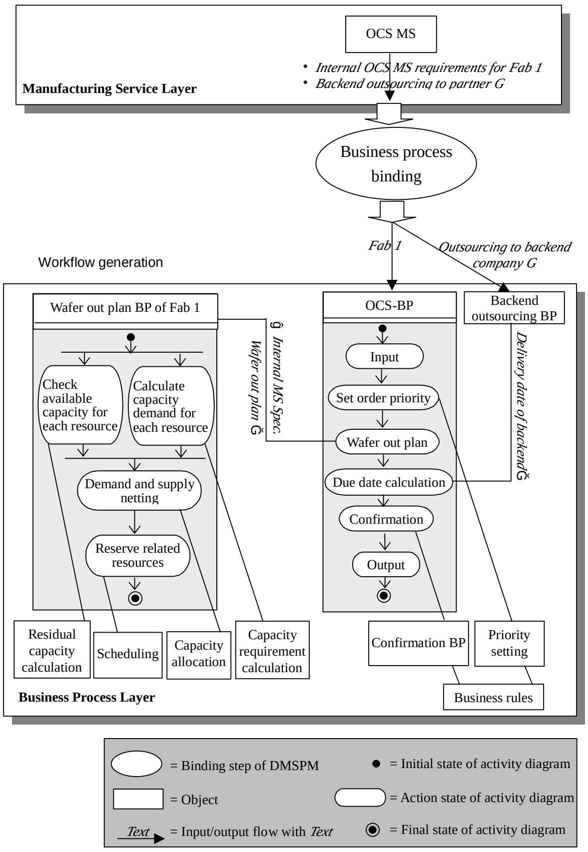

Fig. 10 Business process binding for OCS

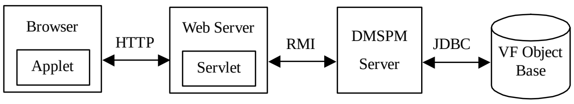

Fig. 11 Prototype system of DMSPM in OCS