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CLOUD MANUFACTURING APPLICATION IN SEMICONDUCTOR INDUSTRY

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ABSTRACT

This paper aims to shed some light on how the concept of cloud manufacturing has been applied to the semiconductor manufacturing operations. It starts with describing the challenges to the semiconductor manufacturing due to evolving of outsourcing business model in global context, then discusses the different forms of cloud manufacturing and proposes the semiconductor industry oriented architecture for cloud manufacturing. Serus is used as a case study to share how the cloud manufacturing has created the values for the customer and its outsourced suppliers in the semiconductor industry.

1 INTRODUCTION

A decade ago, integrated device manufacturers (IDMs / Brands) relied on outsourced manufacturing to reduce costs and off-load excess capacity from their own wafer fab, sort, assembly, test, mark & pack operations (Mohan 2010; Naeher, Suzuki, and Wiseman 2011). In the unidirectional 'buy-sell' business model, the key of outsourcing operations management is to understand the inventory movements, which was adequately handled by B2B integration and legacy supply chain management tools. With the increasing mixes and volumes outsourced to the suppliers, the operating pressures have been magnified as shown in Figure 1.

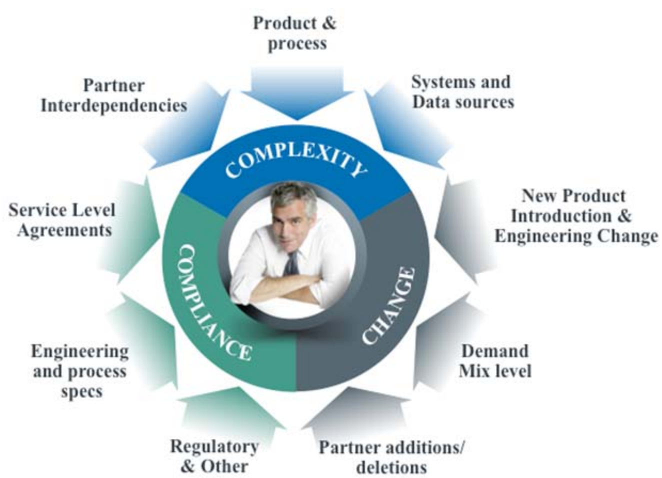

Figure 1: Outsourced manufacturing magnifies operating pressures.

The Brands have ever learned that outsourcing manufacturing does not mean abdicating all responsibility for orchestration, and manufacturing partners' capabilities have to become an extension of its own capabilities. The virtual team of Brands and manufacturing partners demands a robust platform to manage the dynamic change, improve delivery reliability and reduce inventory levels of the global supply chain and outsourced manufacturing operations (Kremers 2010). In the Semiconductor Foundry Sector, TSMC developed the eFoundry® services which is the suite of web-based applications to provide the critical information on design, engineering, and logistics for its customers. However, not all the Brands and outsourcing partners are affordable to build such comprehensive platform. The new era of Cloud Manufacturing might provide the new paradigm or alternative solution to improve the orchestration of the global supply chain and outsourced manufacturing operations.

2 CLOUD MANUFACTURING

Being viewed as Manufacturing-as-a-Service (MaaS), the cloud manufacturing (CMfg) is expected to help the enterprise for achieving the business benefits of reducing the idle capacity and increasing utilization; lowering the entry cost of Small / Medium Enterprises (SMEs) while trying to benefit from high-value manufacturing resources; flexibility to scale the business, etc. (Rauschecker et al. 2011; Wu et al. 2013). According to Zhang et al. (2010), "*CMfg is a new generation service-oriented networked manufacturing model that can provide users distributed in different places with manufacturing resources and manufacturing ability services through centralized management*." Xu (2012) mirrored the NIST's (National Institute of Standards and Technology) definition of cloud computing (Mell and Grance 2011) to define the cloud manufacturing (or manufacturing version of cloud computing) as "*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources (e.g., manufacturing software tools, manufacturing equipment, and manufacturing capabilities) that can be rapidly provisioned and released with minimal management effort or service provider interaction.*" In cloud manufacturing, distributed resources are encapsulated into cloud services and managed in a centralized way. The customers can request services ranging from product design, manufacturing, testing and all other stages of the product life cycle. The cloud manufacturing service platform performs search, mapping, recommendation, and execution of service.

Wang and Xu (2013) developed an Interoperable Cloud-based Manufacturing System (ICMS) to realize the remote collaboration, coordination and interaction among participants on the manufacturing cloud through the STEP (STandard for Exchange of Product data). The LAYMOD platform by Valilai and Houshmand (2013) is based on STEP standard as well. The ManuCloud project (ManuCloud 2014) funded under the European Commission's Seventh Framework Program for Research (FP7) provides a service-oriented IT environment for the next level of manufacturing networks by enabling production-related inter-enterprise integration down to shop floor level. Tao et al. (2011, 2013) proposed the CMfg concept, architecture, core enabling technologies, multi-view models, application of intelligent algorithm, etc. Verl et al. (2013) presented the approach for a cloud-based machine tool control. Chen, Chen, and Hsu (2014) shared a case study of cloud-based logistic management system. Chen (2014) investigated the CMfg application to wafer fab simulation. However, the CMfg systems by the academic research are mostly in prototype, not in viable industrial application yet.

According to Gartner (2014), the industry has been in the fast pace to adopt the external cloud computing service. Through various SaaS solutions, the manufacturing enterprise has transformed the business processes using the latest technology with deep functionality and flexibility at lower capital and operating cost. Some examples are customer relationship management (CRM), human capital management (HCM), travel & expense management, enterprise resource planning (ERP), business-to-business (B2B) solution, Product Lifecycle Management (PLM), supply chain management (SCM) , etc. By connecting with many customers and suppliers and forming an eco-system, some of the SaaS solutions have naturally evolved to be the CMfg platforms for the particular industry, e.g. Serus in supply chain management, OptimalTest in test operations management, etc. for the semiconductor industry.

3 SEMICONDUCTOR INDUSTRY ORIENTED CMFG ARCHITECTURE

As semiconductor manufacturing continues to grow in complexity, the CMfg platform to effectively facilitate the outsourced manufacturing for fast time-to-market at lower cost and with higher quality might include the following functionalities:

- Extensible, real-time integration of heterogeneous data sources from outsourced manufacturing partners;
- Ability to collect and process large volumes of transaction data at appropriate levels of granularity;
- Analytics and data visualization to proactively identify and quickly resolve issues;
- Support for effective collaboration and ease of use within varying environments, regardless of outsourced manufacturing partners' technical sophistication.

This logic architecture of semiconductor industry oriented CMfg platform is proposed as Figure 2. It is a SaaS-based solution to connect the customer with the suppliers. The supplier (physical resource provider) provides the manufacturing resource and ability involved in the whole life cycle of semiconductor manufacturing, which has own "semi-private" systems and is encapsulated into an outsourcing service after the qualification by the customers. The different stakeholders of the customer (resource user) collaborate with the suppliers on the CMfg platform in different aspects of business interests. The CMfg platform consists of the following five layers:

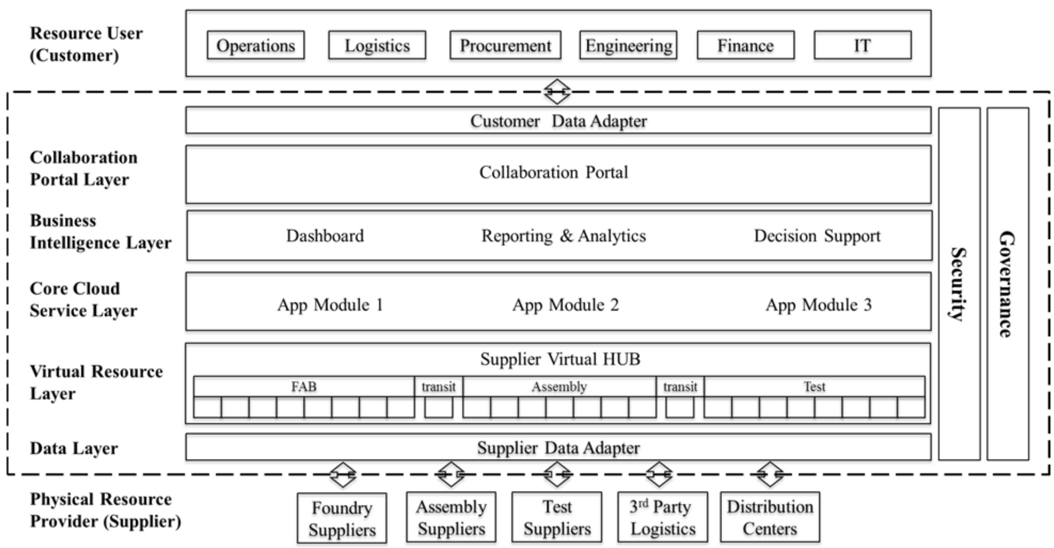

Figure 2: Architecture of semiconductor industry oriented cloud manufacturing.

1. **Data Layer**: handles the inbound and outbound data from the suppliers (e.g. MES system, engineering systems) or customer (e.g. ERP system, PLM system, etc.) via Internet (Https / RosettaNet / FTP). The adapter transforms the data into the standard format and puts them on an enterprise message bus for the next processing by the data processing engine.
2. **Virtual Resource Layer**: models the relationships and interdependencies, retains the detailed view of the virtual factory and global supply chain. The data processing engine will perform the detailed validation and processing before loading the data to the database.
3. **Core Cloud Service Layer**: integrates the core application modules, which are listed in the service catalog, e.g. Supply Chain Management (SCM) service. By referring to the Supply Chain Operations Reference (SCOR, Figure 3) model of the supply chain council, the SaaS solution provider needs to identify the areas of its domain expertise, define the value propositions, then develop the core service application modules accordingly.

4. **Business Intelligence Layer**: provides the capability of 360º view of virtual factory, executive dashboard, enterprise reporting and analytic engine, insight & decision support system.
5. **Collaboration Portal Layer**: provides the user-friendly interface to engage with the users for collaboration or business value creation, e.g. request for quotation, supplier performance management and other insights to action. The collaboration across enterprise boundaries might be in the structured (work flow) or unstructured (conversation over email or Skype) ways.

The cloud-based solution could be hosted in the co-location hosting data center or deployed on the PaaS platform (e.g. Amazon EC2, etc.). The customers are segregated by the multi-tenant technology. The proper IT governance shall be in place to ensure the sustaining of daily service operations and value creation for the business. The service level agreement defines the service commitment of uptime, security and privacy control, problem management, backup, disaster recovery, etc.

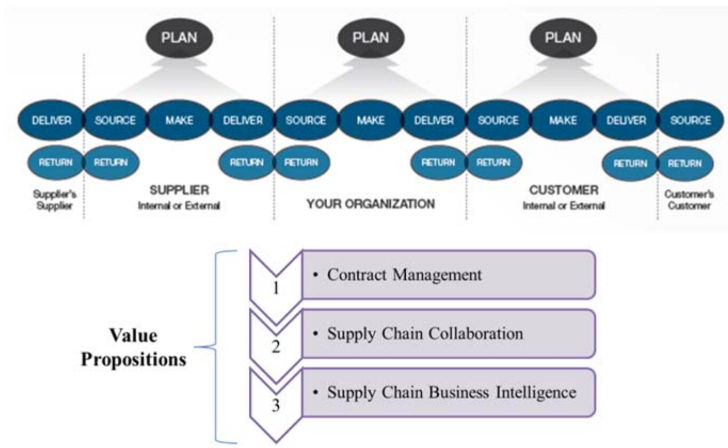

Figure 3: Core cloud manufacturing services.

4 CASE STUDY OF CMFG IN SEMICONDUCTOR INDUSTRY

This paper will use Serus as case study to share how the CMfg concept and architecture have been applied in the semiconductor industry. SERUS CORPORATION is the leading provider of cloud-based manufacturing and Supply Chain visibility and intelligence solutions to semiconductor and other High Tech companies. Serus collects large volume of valuable transactional data from the 300+ suppliers in a timely manner and turns that into actionable insights for fast operational decision making.

4.1 Data Layer: Standard of Data Exchange

In modern manufacturing businesses, the supply chain consists of multiple tiers of partners and suppliers. Collaboration exists both amongst departments within an enterprise, as well as the stakeholders within the business network. Communications and interactions among these participants are difficult due to the heterogeneous environment they operate in, which consists of different protocols, data formats, program languages and platforms. The CMfg platform shall have the ability to process all types of outsourced manufacturing transactions from various business partners: manufacturing, material, financial, scheduled events, engineering change, logistics transactions (shipping, receiving, etc.). A 'common language' is essential for realizing the CMfg across the global manufacturing network. The RosettaNet standard is an industry-wide, open e-business process standard in the global semiconductor industry. It is based on XML and defines message guidelines, interfaces for business processes, and implementation frameworks for interactions between companies. Based on open standards (RosettaNet / EDI), Serus connects to 300+ external outsourced suppliers and their planning & execution systems, directly to customers in their inhouse manufacturing sites and internal ERP, PLM and MES systems as well. The near real time transaction tapping with automated daily reconciliation ensures high data quality. The connection certification and VPN tunnels ensure data privacy and security. The parallel processing and multiple channels per site ensure robust high volume data transfer and scalability.

4.2 Virtual Resource Layer: Modeling

The CMfg platform for the semiconductor industry shall have the ability to naturally and efficiently model complex semiconductor processes such as binning and downgrading, multi-insert processes, model many to many relationships between processes and components. Serus can incrementally create the 3 layers (transformation, flow and supply chain topology) of the network model from transactions received. It provides the ability to collect detailed data, calculate accurate metrics while avoiding the high effort of manual authoring supply chain and manufacturing models. Built upon the network model, the supplier virtual hub becomes the execution engine of the CMfg platform, enabling Brands to create, route, and manage the information of virtual manufacturing and supply chain. Then Serus becomes a system of reference containing accurate and detailed information on what is happening (and what has happened in the past) from all the outsourced and in-house wafer fabrication, test and assembly operations, and distribution networks.

4.3 Business Intelligence Layer: Visibility and Data Visualization

This evolvement of semiconductor outsourcing business requires extreme visibility into multiple dimensions of the extended manufacturing. By monitoring production events and transactions on a real-time, granular level, Brands and their manufacturing partners can discover detailed causes (e.g., shortage and delay issues, excess and obsolete supply, actual performance to target metric, inventory liability, service charge detailed and trends excursions, service over charges, new product manufacturing cost estimates, test & assembly compliance to spec requirement, engineering change order, etc.), immediately collaborate to address issues or risks, and adapt on the fly with decisions that impact output, inventory, costs and customer satisfaction. The sample reports are illustrated as Figure 4.

Figure 4: Sample reports of Serus Analytics.

4.4 Collaboration Portal Layer: Serus Supplier Network

The Serus Supplier Network (supplier.serus.com) provides the Brands with a secure way of connecting and collaborating with their manufacturing service providers and other suppliers. It delivers capabilities in three areas:

- **Connect**: The Business Connect capability powers relationship-building activities in a social network style. Suppliers could build and curate their own business information web pages to market their most updated and specialized capabilities, enabling Brands to explore potential supply partners, ask questions, submit Request for Quotes (RFQs), etc.
- **Collaborate**: The private virtual chat room helps to track the conversations and discussion forums through a single portal, rather than scattering these 'chats' over email and phone interactions. Integrated with the real time operational data, a complete knowledge base can be mined in future.
- **Act**: By enabling Brands to visualize partners and their risk mitigation activity in the context of a global map, organizations can be better prepared to balance a network when political, natural disaster or other events threaten certain geographies.

5 FUTURE TREND: CLOUD MANUFACURING MEETS BIG DATA

When more and more Brands and outsourced suppliers are connected to the CMfg platform, the multi-terabytes transactional data have been exchanged and processed in the ecosystem on daily basis. How to generate the additional values from such big data, it might be interesting to explore further:

- **Industrial Benchmarking**. Leveraging the advantage to view the overall horizon of the industry, the CMfg platform might be able to produce the industry benchmarking report as the following example (Brand A) in Figure 5 by integrating its rich data set with other public data sources (e.g. SEC data). It will enable the Brands to drive the positive ROI.

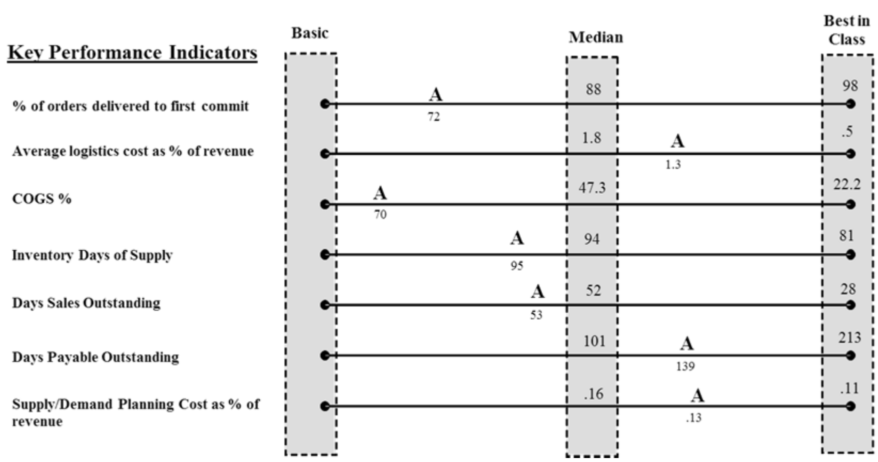

Figure 5: Industrial benchmarking.

- **Variation Identification**. By effectively segmenting and analyzing the huge amounts of structured and unstructured data being collected from the outsourced manufacturing suppliers, the CMfg platform might be able to quantify the relationship among variability, lead time and utilization, turn it into actionable recommendations on how to reduce the variation in manufacturing operations.

However, in order to mine the data, the CMfg platform owner has to obtain the permission from the trading partners. It might be challenging due to the concern of privacy and security. A good starting point might be to ask around, “Who might find this information valuable?” Another provocative thought: “What would happen if we will provide our product or service free of charge or exchanging with some values?" or perhaps more compelling, "What if a competitor did so?" The responses should provide indications of the opportunities for disruption by embracing the big data initiative.

6 CONCLUSION

Inspired by the great success of cloud computing, the cloud manufacturing is expected to help for transforming the manufacturing from production-oriented to service-oriented. The implementation of the SaaS solution makes the cloud manufacturing or manufacturing version of cloud computing viable. A semiconductor industry oriented CMfg architecture is proposed and validated with a real SaaS solution. Instead of mirroring the model of the cloud computing, the authors emphasize more how the CMfg could add the value to the semiconductor industry.

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