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Virtual production line based WIP control for semiconductor manufacturing systems

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Abstract

The explosive growth of data acquisition and increasing number of machining processes makes extremely difficult to deliver precise information to the proper users at the right time by relying on a centralized work-in-process (WIP) control system in manufacturing. This article presents a potentially practical solution to a manageable and well-distributed WIP control system by addressing issues such as real time performance, scalability, and reconfigurability. By taking advantage of the advances in distributed computing technologies multiple WIP control instances performing different subsets of control and management responsibilities can be spawned from a server repository, running on geographically dispersed networked computers. These spawned WIP control instances are coordinated and synchronized using the concept of virtual production lines (VPLs). WIP control algorithms for implementing real time "pull" operations, leveraging WIP levels, and resolving resource sharing are proposed. Certain validation has been conducted in an industrial testbed to confirm the applicability of the proposed VPL-based WIP control solution.

Keywords: Work-in-process; Virtual production line; Process flow; Production transition; Distributed computing

1. Introduction

As semiconductor business environments are challenged by the rapid changes in business needs and customer demands, customer satisfaction becomes one of the most important factors for manufacturers to stay ahead of competition. One of well-recognized strategies for providing customers with satisfactory services is to continuously improve manufacturing and service responsiveness. A proven successful means in improving the responsiveness of manufacturing systems is to deploy an efficient and effective shop floor work-in-process (WIP) control and management system, which controls the material flow, monitors the WIP level for each machine/stocker, tracks the statuses of materials on the shop floor in a timely way, and also real time responds the requests from the shop floor. It is the availability of pertinent and real time production data that timely well-informed decisions could be made and satisfactory customer services provided.

A typical advanced semiconductor manufacturing control and management system is of a hybrid nature (Fig. 1). Between cells,[1] a heterarchical architecture nature takes place; while within a cell

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[1] Term "bay" is used in many wafer fabs. A bay can be a fully automatic area, semi-automatic area, combination of one fully automatic area and one semi-automatic area, or combination of multiple fully automatic areas and multiple semi-automatic areas. Usually stockers and/or Intra-bay robots are deployed within each bay (Matsuyama and Niou, 1993).

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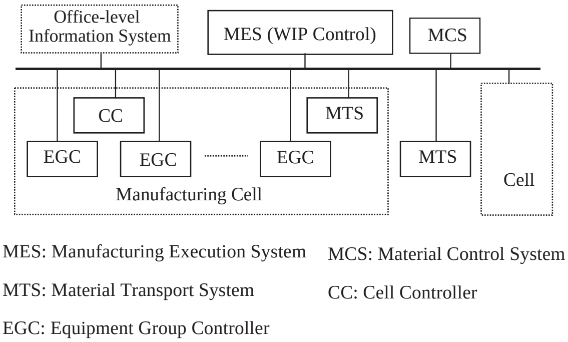

Fig. 1. WIP control used in shop floor control systems.

it locally deploys a hierarchical architecture. A manufacturing execution system (MES) is a shop floor information system that provides floor production control, WIP control and management, and floor accounting functions, and acts as the interface between enterprise planning (i.e., office-level information systems) and shop floor execution (e.g., cell controllers). A cell functions as an autonomous manufacturing entity. Each cell consisting of a group of equipment in the same area may accomplish one or several successive manufacturing processes. Between cells, a material control system performs the shop level material flow control and tracking. The material control system ensures that all the necessary materials will be delivered to cells in an optimal manner.

Within a cell, a cell controller supervises a group of equipment. It first refines all the task assignments from the MES. It then executes the refined tasks through coordinating the activities of all the equipment group controllers (EGCs) within the cell. An EGC is considered as an equipment software driver, which provides the interface between a cell controller and physical machines. EGCs command all the equipment to accomplish the detailed manufacturing operations as assigned. An internal material transport system receives material delivery commands from the WIP control and optimally delivers the materials to the right equipment/storage at the right time.

Currently most semiconductor manufacturing fabrication facilities use a cell/process layout configuration (Matsuyama and Niou, 1993). An MES[2] is configured using one or a few predefined "super production lines" based on such a facility resource model, equipment proximate information, and administrative organization structures (White et al., 2000; SiView, IBM SiView standard). Materials are usually released in batches. For each batch, when one process is done, operators check the MES and get a list of available equipment for next process. If there are many choices, simply it is at operators' or production managers' discretion to pick equipment to perform the process.

For instance, SiView is a leading centralized MES product deployed by many semiconductor manufacturers (White et al., 2000; SiView, IBM SiView standard). It utilizes client/server architecture. On the client side, SiView provides a thin GUI interface; the major functions provided for users are (1) getting information on lot, consumables, setup, tooling, and process specifications before a process gets started and (2) recording data on the process, consumed consumables, and quality assurance as the process gets completed (White et al., 2000). On the server side, SiView includes best manufacturing practices and application scenarios ranging from MES specification manager and material manager to web reporting.

With the quick advance of semiconductor technologies, semiconductor manufacturing processes have become more and more complicated. The resultant manufacturing systems become more competent but also complicated, giving rise to more intensive and complex equipment setup and recalibration in production transitions (Blose and Pillai, 2001). Consequently, a currently and widely adopted centralized WIP management system that runs as a mammoth and monolithic application is losing its designated performance due to the explosive growing need of data acquisition and analyses. In addition, inflexibility and lack of good reconfigurability and scalability are also the drawbacks of a centralized WIP control system (Sturm et al., 1999; Qiu et al., 2002).

[2] WIP tracking, control, and management are the nucleus of most MES systems (SiView, IBM SiView standard). As a matter of fact it is not unusual for an MES to perform only WIP control and management.