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Simulation study for a proposed segmented automated material handling system design for 300-mm semiconductor fabs

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ABSTRACT

With the increase in the size and weight of 300-mm wafers, the factory area must be enlarged accordingly. Due to the flow of material over long distances, the elimination of manual wafer handling has become necessary. Consequently, an automated material handling system (AMHS) is required for 300-mm semiconductor manufacturing facilities. The design of an AMHS must not only be capable of meeting numerous complex material handling requirements, but it must also simplify control and reduce capacity loss. In this study, a segmented dual-track bidirectional loop (SDTBL) design for an AMHS is proposed. The configuration is based on a double-loop flow path structure that is divided into non-overlapping segments, each containing a certain number of vehicles operating in bidirectional mode. A transfer buffer is set to enable conversion between segments and connect each independent zone. This structure eliminates congestion and blocking without requiring additional investment by operating vehicles on mutually exclusive tracks. The segmentation strategies and steps for two scenarios are developed in this research, and a simulation is performed to evaluate the performance of each segmented strategy. The simulation results show that the proposed strategies can reduce the cycle time and increase stocker utilization by up to 55.55% and 39.39%, respectively, while the throughput remains the same. The proposed design has great potential for practical application.

1. Introduction

The trend in semiconductor wafer fabrication facilities (fabs) has been progressing from 200-mm to 300-mm wafers. While the unit cost of a manufactured 300-mm wafer is approximately 45% higher than that of a similarly manufactured 200-mm wafer, the larger wafer has a 40% lower die cost due to its higher die count [9].

A 300-mm fab costs between approximately 2 and 4 billion US dollars, of which some 70% is invested in process tools. Due to the high tool costs, many programs, such as SEMATECH in the USA, have been initiated to improve the operational efficiency and advance manufacturing technologies associated with the wafer process.

A 300-mm wafer travels approximately 8–10 miles during processing and 250 process tools are typically used for the several hundred individual process steps performed on the wafer [1]. The material handling of a 300-mm wafer is highly automated in order to improve fab productivity [12].

A fab is usually equipped with an overhead-monorail automated material handling system (AMHS) in conjunction with automated storage/retrieval systems (stockers) for interbay automation and intrabay material handling automation. The

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general layout envisioned by I300I for 300-mm fabs had the configuration of a spine [25], similar to those of an AMHS, which forms a material flow-loop within the facility.

The commonly adopted technology in an AMHS for a 300-mm fab is to use an overhead hoist transport (OHT) and overhead hoist vehicle (OHV) for inter- and intrabay material handling, respectively. The central aisle is typically designed with two physically separate loops so as to allow unimpeded two-way travel along the central spine of the facility, with crossover turntables for reversing travel direction [18,27].

The AMHS configuration with a spine layout is considered to be the standard design for a 300-mm fab, although several variations on component design, such as for the power system or the vehicle type, may be utilized by different AMHS suppliers. The present study explores the segmented AMHS design for a 300-mm fab. The segmented design concept is based on the tandem automated guided vehicle (AGV) design [4,5]. The term segmented bidirectional single-loop (SBSL) denotes a single-loop flow path divided into non-overlapping single carrier segments. In the present study, the SBSL proposed by Sinriech et al. [21] is used as the base concept. This concept is combined with a dual-track device that provides more options to the segmented zones. Therefore, a segmented dual-track bidirectional loop (SDTBL) design for an AMHS is proposed in this work. The configuration is based on a double-loop flow path structure that is divided into non-overlapping segments, each containing a certain number of vehicles operating in bidirectional mode.

In the SDTBL design, transfer buffers are located at both ends of each segment as input/output buffers. Thus, a carrier can deposit loads that are headed to other segments and can pick up loads from other segments. The carrier has the capability to travel clockwise or counterclockwise on each segment depending on which direction produces the shortest path to the destination point. Due to the tandem design concept, each segmented loop is served by one carrier and is free from the transportation blocking problem. Thus, the SDTBL system can reduce time loss stemming from congestion, blocking, and interference. Notably, the reduction in time loss can lead to additional economic benefits. The SDTBL flow structure was designed in an attempt to improve the performance of a single-loop flow path system and does not require carrier selection (only one carrier per segment), routing, or intersection flow scheduling. In addition, no mutual carrier interaction is possible, making the SDTBL system relatively simple to control and advantageous in industrial applications.

The present work serves as a pilot study for the adoption of the segmented design in an AMHS. A practical application is adopted in order to provide an empirical illustration. The case problem is formulated by simulation. Heuristics are proposed to generate several different segmented design scenarios, and the performance of each is subsequently evaluated by simulation.

The remainder of this paper is organized as follows: Pertinent literature is reviewed in Section 2, while background information for the case study is provided in Section 3. Details of the proposed methodologies and an empirical illustration are discussed in Sections 4 and 5, respectively, and conclusions and future research opportunities are addressed in the final section.

2. Literature review

A 300-mm wafer travels approximately 8–10 miles during processing and 250 process tools are typically used for the several hundred individual process steps performed on the wafer. This makes material handling in semiconductor manufacturing factories a critical operation. To transport wafers in a 300-mm facility, front-opening unified pods (FOUP) with a carrying capacity of 25 wafers are employed. With an increase of more than 200% in the manufacturing area, elimination of the manual handling of wafers has become necessary. Facility design and material handling system design are the two major issues that impact the efficiency of a wafer fab. Because these areas are interdependent, the two designs are addressed simultaneously. According to International SEMATECH, AMHSs typically have a stocker in each bay that serves as a connection point between the interbay and intrabay transport systems. An overhead shutter (OHS) or monorail is used to transport material between stockers, and an OHT, AGVs, rail-guided vehicles (RGVs), conveyors, and person-guided vehicles (PGVs) are employed with production equipment and stockers for intrabay transportation of work-in-process (WIP) [1].

The general layout envisioned by I300I for 300-mm fabs has the configuration of a spine. This layout has equipment installed in several bays, all connected by a central aisle. In this configuration, stockers are located at the junctions between the main aisle and each bay. An AMHS with a spine configuration typically has a uni-directional flow loop and crossover turntables for changing the travel direction. Another widely used AMHS architecture in a bay-type layout setting is a perimeter configuration, which is typically designed with two physically separated loops. Crossover turntables are again used to change the travel direction [1].

The AMHS efficiency has a significant impact on the operational efficiency of a fab, particularly with regards to the operational efficiency of a 300-mm fab [1]. Therefore, this factor is regarded as critical for productivity improvement [10,17,2,24,16,12,14].

Yang and Peters [26] proposed a solution algorithm for a fab layout with a spine-like configuration using a modified quadratic set covering problem (QSCP) formulation. Peters and Yang [18] subsequently used a space-filling curve approach to solve the facility design problem. Yang et al. [27] proposed a hybrid search methodology to obtain a near-optimal solution for the integrated layout and material handling system design.

Ting and Tanchoco [23] proposed two alternate rectilinear layout configurations, a single spine layout and a double spine layout, for the overhead material handling track design. The researchers used mathematical models to solve these problems. Lin et al. [15] suggested the connection of transport AMHSs to link the interbay and intrabay. The authors indicated that the