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The heuristic preemptive dispatching method for convey-based automated material handling system of 450 mm wafer fabrication

Chia-Nan Wang [a], Yueh-Hsiu Lee [a,b], Hsien-Pin Hsu [c,*], Dinh-Hiep Nguyen [a,d]

[a] National Kaohsiung University of Applied Sciences, Kaohsiung, Taiwan
[b] Metal Industries Research and Development Centre, Kaohsiung, Taiwan
[c] National Kaohsiung Marine University, Kaohsiung, Taiwan
[d] Foxconn Electronics Inc., Viet Nam

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ABSTRACT

The 450 mm transition of wafer fabrication is the current trend of semiconductor industry. However, the increased size and weight of wafers pose challenges on wafer handling and transportation. To address this issue, conveyor-based automated material handling system (AMHS) has been suggested as a solution due to its advantages. However, the lack of an effective and efficient dispatching method will make a convey-based AMHS to remain suffer traffic-jams problem and short the capability to handle hot lots to meet customer needs. In this study, a heuristic preemptive dispatching method (HPDB) is proposed for controlling the movements of wafer lots in a convey-based AMHS that is restructured based on activated roller belt (ARB) and to be used for 450 mm wafer fabrication. To investigate the effectiveness of the HPDB, simulation experiments have been conducted and the results obtained from HPDB has been compared to that obtained from HPD. The experimental results show that HPDB outperforms HPD in terms of average delivery time, with the advantages of 55.11% for hot lots and 55.76% for normal lots. This indicates that HPDB can better solve the traffic-jam problem and reduce transportation time.

1. Introduction

Though with a short life starting from about five decades ago, the semiconductor industry has experienced fast advancements boosted mainly by two drivers: the technology advancement and the wafer size increase. Both of the drivers have the benefits of productivity enhancement and production cost reduction. The technology advancements focus on miniaturizing the components of integrated circuits, which almost follows the Moore's Law (Mack, 2011) that predicates the number of components per chip doubled roughly in every 24 months. However, due to the physical limits of nanotechnology the increase of wafer size appears also attractive. For the last two transitions of wafer size increase, one from 150 mm (6 in.) to 200 mm (8 in.) and another from 200 mm to 300 mm (12 in.), each has achieved a 30% cost reduction per chip. Currently, the semiconductor industry faces the transition of migrating from 300 mm to 450 mm (16 in.) wafer size.

Besides the two drivers, the International Technology Roadmap for Semiconductors (ITRS, 2013) and the International SEMATECH Manufacturing Initiative (ISMI, 2015) both have contributed a lot to the advancement of semiconductor manufacturing. The ITRS report update overview provides a whole picture of semiconductor industry development whereas the international organizations such as ITRS, ISMI and other researchers have been studying and presenting the requirements for the migration from 300 mm to 450 mm wafer fabrication.

However, the transition form 300 mm to 450 mm wafer fabrication will encounter some challenges. One of the main challenges is the difficulty of transporting those 450 mm wafers due to their increased size and weight, prompting the need of an effective automated material handling system (AMHS). For wafer transport, there are different kinds of AMHS, including automatic guided vehicle (AGV), rail-guided vehicles (RGV), overhead shuttle system (OHS), overhead hoist transport (OHT) and conveyor. Among them, the OHTs have been widely used in current 300 mm wafer fabs. Driven by belt hoisting mechanism, an OHT employs vehicles to directly access the load port of stocker or process equipment. However, the efficiency of an OHT depends heavily on the vehicles' characteristics and control mechanism of this system. For instance, in an OHT insufficient vehicles will lead to longer waiting times whereas excessive vehicles will cause traffic-jam problems. Due to this disadvantage, some researchers have suggested using conveyor-based AMHS as

* Corresponding author at: 142, Hai-Chuan Road, Nan-Tzu District, Kaohsiung City 81157, Taiwan.
E-mail address: hphsu@webmail.nkmu.edu.tw (H.-P. Hsu).

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the next generation AMHS. For example, Pettinato and Pillai (2005) proposed using continuous flow transporters (CFT) for 450 mm wafer fabrication; Nazzal and Nashar (2007) suggested using conveyor-based AMHS as an alternative solution to the existing vehicle-based AMHS. Their suggestions were based on the advantages of conveyor-based AMHS, including high transport capacity, high throughput, short and predictable delivery times and low costs, higher storage capabilities near the processing equipment, and higher flow rate of wafers into the processing equipment.

Though with these advantages, a traditional conveyor-based AMHS is found still likely to encounter the traffic-jam problems due to the one-direction movement characteristic of conveyor that tends to block the delivery of following lots of a lot being loaded into or unloaded from a machine. In addition, when there exists a high-loading bay it is also likely to incur traffic-jam problems. Another problem faced by a wafer fab is the need to prioritize lots in order to serve hot lot first to meet customer needs. In past studies, this requirement has been rarely taken into account. To address this problem, Liao and Wang (2006) had proposed a differentiated preemptive dispatching policy (DPD) and Wang and Chen (2009) had proposed a heuristic preemptive OHT dispatching rule (HPD). However, the two dispatching rules are proposed for the OHT used in a 300 mm wafer fab environment. As a result, there is still a lack of effective dispatching rule for the conveyor-based AMHS to be used in a 450 mm wafer fab to deal with the problems of traffic-jam and lot prioritization.

To address this gap, this research continues to propose an effective heuristic preemptive dispatching method (PHDB), based on a restructured conveyor-based AMHS using activated roller belt (ARB) (ARB sortation systems, 2014), for 450 mm wafer fabrication. The application of ARB to restructure a traditional conveyor-based AMHS is due to its advanced features that allow multi-directional and selected movements. The ARB is a modular plastic conveyor belts that can increase conveyor productivity and decrease production costs and downtime in a plant (ARB sortation system, 2014). Fig. 1 shows the design of ARB. On an ARB conveyor, products rest on free-spinning angled rollers rather than on the belt surface. These rollers extend above and below the belt surface and are positioned at an angle in relation to the direction of belt travel. Rollers that are activated by the carry way surface below move products across the belt in the direction of roller orientation rather than the direction of belt travel. As a result, an ARB-equipped conveyors can change the direction, alignment, location, and speed of an item independently, without using rails or complicated mechanical controls. The application of ARB is showed in Fig. 2.

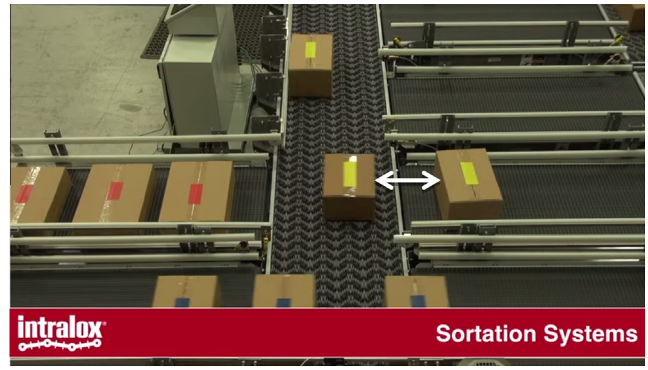

Fig. 2. Application of ARB (ARB sortation system, 2014).

In addition, as heuristic rules are simple and applicable for practical-oriented decision support (Pratap, Daultani, Tiwari, & Mahanty, 2015), the HPDB is proposed in the study to help control the movements of selected items with the aim to minimize the transport delay of normal lots while expediting the delivery of hot lots. To investigate its effectiveness, the HPDB has been compared to the HPD proposed in Wang and Chen (2009) by simulation approach under a same simulation environment. The average lot delivery time (ALDT) is used as performance index.

The rest part of this study is organized as follows. Section 2 gives a literature review and an introduction to the ARB. Section 3 details our approach that includes the structural changes to a traditional conveyor-based AMHS and the development of an effective dispatching method. Section 4 performs simulation experiments and analyzes simulation results. Section 5 presents a conclusion and highlights some future research directions.

2. Literature review

Most of the current 300 mm wafer fabs use OHTs. As a conveyor-based AMHS system still keeps the advantages of OHT, reviewing relevant OHT literature to improve a conveyor-based AMHS for 450 mm wafer fabrication is reasonable and necessary. Lin, Wang, and Wu (2003) proposed a hybrid push/pull (PP) dispatching rule to operate an OHT in a 300 mm wafer fab. Their simulation results showed that the PP could reduce WIP and cycle time. Liao and Fu (2004) proposed a modified nearest job first (MNJF) dispatching policy to operate an OHT in a 300 mm wafer

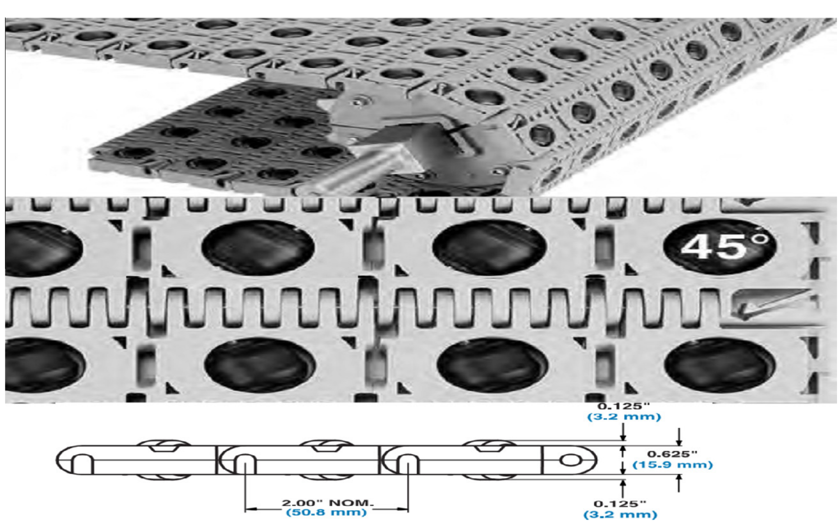

Fig. 1. ARB's design (ARB sortation system, 2014).