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Facilitating an advanced product layout to prioritize hot lots in 450 mm wafer foundry in the semiconductor industry

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ABSTRACT

With economic costs scales and the technology improvement, the semiconductor manufacturing has become a global industry in recent years. Automated material handling systems (AMHS) using conveyors have been recently proposed as a technology option for next generation wafer fabrication facilities. This technology seems to provide an increasing capacity for moving and storing wafers in a continuous flow transport environment. Because of increasing the size, weight, and throughput of wafer, workers cannot handle the heavy and great amount of wafer; hence the automated material handling systems (AMHS) have recently become the indispensable equipment in wafer fab factories. For this reason, this study proposed an effective conveyor dispatching rule: Conveyor Prioritize Dispatching (CPD) to reduce the handling delay of hot lots. This research conducted the simulation experiments by building a 450 mm wafer fab and compared CPD with Nearest Job first (NJF). Simulation results show that the distributed storage approach provides improved performance by 94.54% under CPD rule; however, these systems require more capital investment than that needed for the centralized storage approach. This study proves that CPD method can efficiently reduce the cycle time of hot lots in every load configuration and improve productivity.

1. Introduction

Semiconductor industry develops rapidly in recent years, and it has become a crucial economic indicator all over the world. According to Moore's Law, semiconductor wafer manufacturers are constantly searching opportunities to improve productivity while reducing costs and cycle times within wafer fabs. Following the increase of wafer size, the cost of wafer manufacturing will reduce. With the improvement and growth in technology, International technology roadmap for semiconductor (ITRS, 2011) forecasts of wafer manufacturing, wafer scale development, and identifies the 450mm wafer is critical research and develop requirements of the semiconductor manufacturers over the next generation factory (NGF). The ITRS International roadmap committee (IRS) expects the high volume of 450mm wafer manufacturing tools to be available between 2012 to 2014 for pilot lines; with possible production manufacturing from 2015-2016 and beyond. The results are demonstrated in Fig. 1.

From the perspectives of Intel (2005), the development technology on the future size of the increase can reduce manufacturing costs in 450 mm wafer fab. As shown in Fig. 2, the wafer sizes have been increase stably together with the development of semiconductor industry. Thus, we can see (1) device and process technology innovations via two-year technology nodes, including transistor design improvements, new materials, and lithography feature size reductions; (2) chip and product design improvements that enable new capabilities or optimize existing ones, such as two-bit per cell flash memory; (3) wafer size increases that enable more cost-effective output. The weight of 450mm wafer fab is heavier to transport manually, therefore the automated material handling system (AMHS) is more important to available on transportation. There are several transports of AMHS in wafer fab, including automatic guided vehicle (AGV), rail-guided vehicles (RGV), overhead shuttle (OHS), and overhead hoist transport (OHT), conveyor, and so on.

The AMHS has two major portions: one is inter-bay loop of transfer between production centers; the other is intra-bay loop of transfer within a production center (Montoya-Torres, 2006). The inter-bay material handling system is set in the

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center and connects all bays. Fig. 3 shows the inter-bay loop. An intra-bay loop includes the sensor to detect the finished production, conveyor rail and equipment's load ports. The lot moves along the conveyor rails, and continuously moving in the same direction. When the lot reaches equipment, the equipment catches the lot automatically.

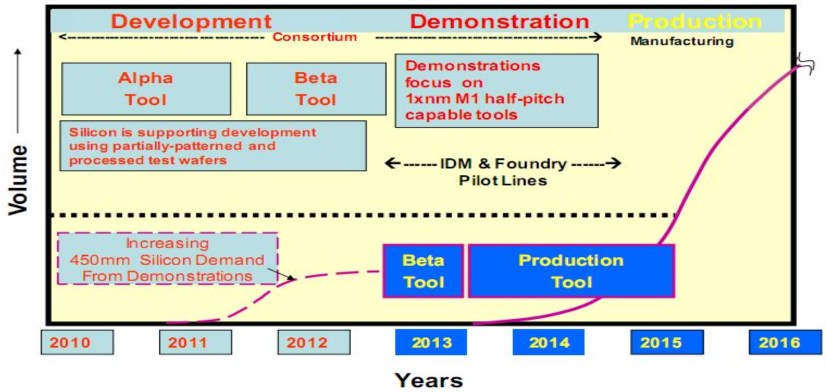


Fig. 1: A typical wafer generation pilot line and production "Ramp" curve applied to forecast timing targets of the 450 mm wafer generation

In the 300mm, the AMHS environment usually uses the OHT technology dispatching rules to transport the lots. However, in the 450mm semiconductor fab, the heavier lots and process time increased, some scholars confer on conveyor transport as the main transport tool. Nazzal et al. (2008) described continuous flow transport (CFT) which likes conveyors, provide higher transport capacity, shorter and more predictable delivery times, and lower cost than other traditional AMHS methods. The OHT is a major trend in 300mm AMHS environment. The scholar proposed conveyor-based AMHS in 450mm wafer fab. The OHT will not load due to increased volume of 450 mm wafers. Hsu (2010) analyzed the production transport on differences AMHS in 450 mm wafer environment. Results demonstrated that the conveyor-curved gives a better performance than conveyor - turntable and OHT. Basing on consideration of space, equipment and the carrier transfer without blocked, the conveyor will be the new concept of next generation factory AMHS. Accordingly, the research selects conveyor-curved as our study tool in 450 mm AMHS. The conveyor executes transporting work by single movement direction in each track.

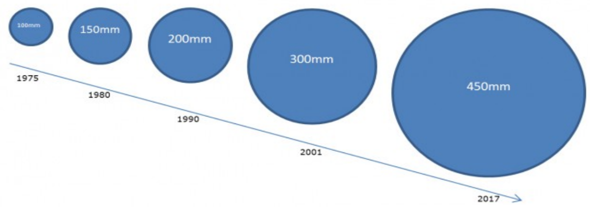


Fig. 2: Wafer size increases have been used effectively over the past 30 years

This research mainly discusses the transport which in the semiconductor fab AMHS. In 450 mm environment, the conveyor is set to move the same direction in any loop. The 450 mm automatic transport system should differentiate its services to different priorities of process requirement in order to cope with frequent process changes and fine tunes as well as the small production volumes of products. The Conveyor management should provide the transport services to minimize the transport delay of hot lots with least impacts to the delivery of normal lots in 450 mm AMHS.

2. Background information

Leachman et al. (2007) said semiconductor industry has been one of the most capital intensive and complicated industries driven by Moore's Law for continuous cost reduction and technology evolution. Chien et al. (2007) pointed out new wafer size platforms allow equipment suppliers and IC makers to incorporate advanced process technologies and tool designs for better productivity. Indeed, it took only about 6 years from 150mm to 200mm, yet it took almost 10 years from 200mm to 300mm. The critical success factor that silicon wafers, equipment and cost structure change for 450mm migration to provide a baseline for the industry discussions to ensure that the next wafer size transition is well planned and effectively coordinated (Figs. 3, 4 and 5).

Wafer manufacturing demands production services of short cycle time and on time delivery in order to satisfy customer requirement. The products of high priority are usually granted as hot lot in a semiconductor fab. Operation of hot lots can be either capacity reserved for no wait services or receive more profits.

This research mainly discusses the conveyor transport which is in the semiconductor fab AMHS. In 450 mm environment, the conveyor is set to move the same direction in any loop. The 450 mm automatic transport system should differentiate its services to different priorities of process requirement in order to cope with frequent process changes and fine tunes as well as the small production volumes of products. The Conveyor management should provide the transport services to minimize the transport delay of hot lots with least impacts to the delivery of normal lots in 450 mm AMHS.

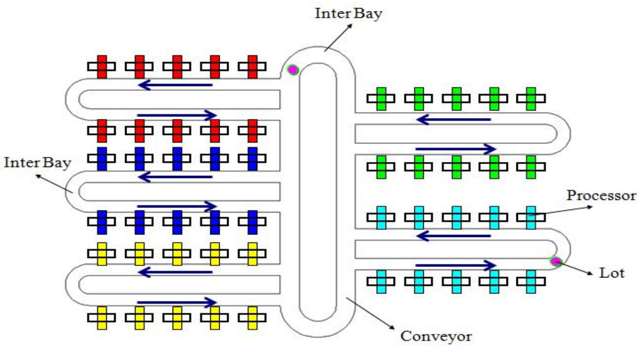


Fig. 3: Inter-bay loop

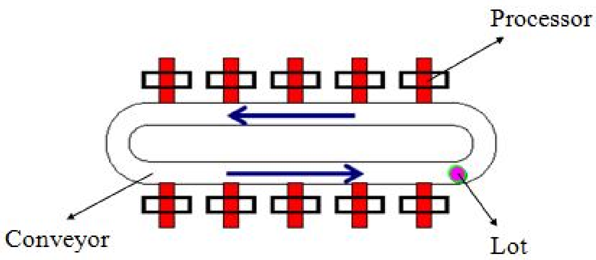


Fig. 4: Intra-bay loop

This research mainly to simplifies systems under the principle, we use software of simulation to discuss a Conveyor Prioritize Dispatching (CPD) effectively and provide good transport services for lots under 450mm semiconductor fab. This paper is to provide the conveyor transport system to minimize the transport delay of hot lots in 450mm AMHS. A simulation model is built based on international SEMATCH (ISMI) 450mm guidelines (2009).

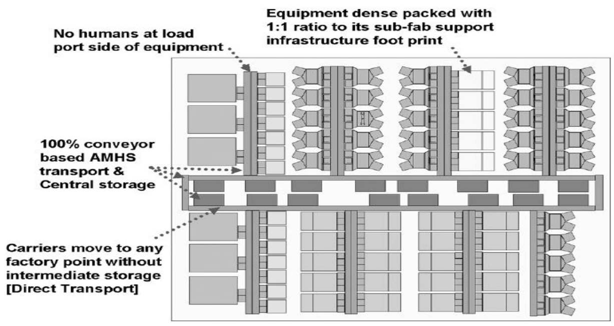


Fig. 5: 450 mm factory, facilities and AMHS vision (Pettinato and Pillai, 2005)

Govind et al. (2011) proposed an alternative closed queuing network-based approach to simulating intra-bay AMHS in semiconductor manufacturing. Compare an explicit AMHS simulation and the queuing network approximation both in terms of the information needed to develop the models, and in terms of the output statistics that are available from the two models. The approximation is able to provide reasonably accurate estimates of the major performance measures that are tracked in the complex AMHS.

Tu et al. (2013) provide an adaptive multi-parameter based (AMP) dispatching policy is proposed to obtain better performance of the inter-bay material handling systems and semiconductor wafer fabrication systems. With experimental data from an inter-bay system of 300 mm semiconductor wafer fabrication systems and running simulation experiments, it is demonstrated that the proposed approach has better performance in terms of cycle time, throughput, due-date satisfaction rate, and vehicle utilization compared to conventional single-attribute and multi-attribute dispatching methodologies.

Nazzal and El-Nashar (2007) researched areas related to closed loop conveyors are identified, which include deriving analytic methods to model large scales implementations of closed-loop conveyor material handling systems, and developing analytical and simulation models which simultaneously address multiple design and control problems.

Nazzal et al. (2008) proposed an analytical model useful in the design of conveyor-based Automated Material Handling Systems (AMHS), the objective is to correctly estimate the work-in-process on the conveyor and assess the system stability. Fig. 6 illustrates the CFT-based inter-bay system with crossovers. The system is composed of a unidirectional closed-loop CFT with four 90° turntables located at the corners, and N stockers (stations). Each stocker is used as an entry (or exit) point to (from) a bay. It is assumed that no stocker is located between the turntables on the shorter sides of the CFT. The system also includes crossovers, located perpendicular to the longer sides of the CFT with two turntables for each crossover.

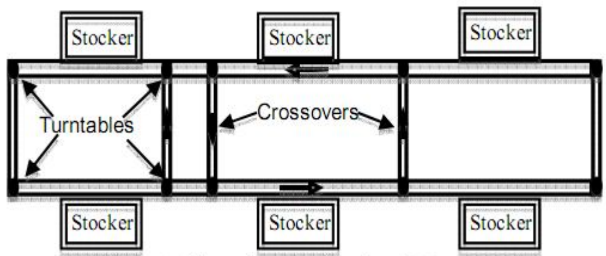


Fig. 6: An illustration of an inter-bay CFT system (Nazzal et al., 2008)

3. Methodology

3.1. Defining bottleneck

A bottleneck operation is an operation in a sequence of operations whose capacity is lower than the capacities of other operations in the sequence. As a consequence, the capacity of bottleneck operation limits the system capacity; the capacity of the system is reduced to the bottleneck operation. Fowler et al. (2002) remarks that “The presence of bottlenecks implies that careful attention and control in areas not directly influencing the bottleneck may have little effect on system performance”. Gupta and Boyd

(2008) describe a system's throughput is usually determined by bottleneck resources, which is the fundamental principle of the theory of constraints (TOC). The marginal value of time at a bottleneck resource is equal to the throughput rate of the whole production system while the marginal value of time at a non- bottleneck resource is negligible. The system performance can be improved by focusing on the bottleneck resource. In order to show the obvious bottleneck resource, we expand the output range between efficiency and bottleneck performance. The output of the first intra-bay is 100 lots per hour. The output of the second intra-bay is 85 lots per hour. The output of third intra-bay is 106 lots per hour. The output of the forth intra-bay is 101 lots per hour. The output of the last intra-bay is 194 lots per hour. Obviously, the output of second intra-bay is least. Basing on the output of the bottleneck, we calculate the input for each experiment.

3.2. Conveyor prioritize dispatching method

Defining a transport job as a macro of transfer commands, there are four steps as follow: First, when a lot is completed process by a process machine, the machine will transmit a non-processed lot signal to material control system (MCS) and sends this lot to the conveyor. Second, the MCS finds an empty machine of next destination of this lot and move this lot to destination. Third, if not any empty destination machine is available, then move this lot to the intra-bay of destination machine. Keep waiting in that intra-bay until empty destination machine is available and move to this available machine. The objective of conveyor dispatching is to minimize delivery time for hot lots while incurring the least impact to normal lots.

Analyzing the conveyor operation and theoretical moving time, we find the lot waiting time is non-profit-generating. Higher priority products should enjoy their privilege of preemptive transportation against those with lower priority. Therefore, we propose a heuristic conveyor dispatching method to expedite the movement of hot lots in order to minimize conveyor delivery time.

Conveyor will move along the same direction continuously. Considering a set of transport jobs by conveyor, an available machine is dispatched to highest priority job. That is, once has the highest priority job must reserve an available machine to serve this job, any other ongoing transport on conveyor until this highest priority job completes. If no such highest priority job exists, all jobs follow the first-meet; first serve for normal transport job.

The heuristic algorithm was designed in detail as bellows.

3.2.1. Overall rules

Step 1: MCS controls all non-processed lots to move to the belonging intra-bay of destination machines.
Step 2: If a hot lot job appears, it will follow the hot lot rule.
Step 3: The rule of "first meet, first serve" is applied to deliver the non-processed lots into the nearest available machines.
Step 4: If not any available machines at a moment, the non-processed lots will keep moving in this intra-bay to wait for available machines happen.
Step 5: The intra-bay conveyors load the unprocessed lot into the available machine.
Step 6: Change these processing lots to be the status of processing. After processed, change to be the status of non-process and unload this lot back to conveyor.
Step 7: If a lot is finished all its processes, the lot will be moved to the warehouse. Otherwise, continue back to step1.

3.2.2. Hot lot rules

Step 1: The MCS reserves the nearest available machine to execute the non-processed hot lots.
Step 2: If more than one non-processed hot lot is found, the available machine will follow the "first meet, first serve" rule.
Step 3: If there is no available machine, the non-processed hot lots will keep moving in the intra-bay and wait for the next available machine.
Step 4: The intra-bay conveyors load the unprocessed hot lot into the available machine. Then go back to the step 6 of overall rules.

To visualize the mentioned rules, we create Fig. 7 which illustrates the conveyer transport rules.

3.3. System simulation platforms on Flexsim

According to Hou (2013), Flexsim is a powerful analysis tool that helps engineers and planners make intelligent decisions in the design and operation of a system. Flexsim can build a 3-dimensional computer model of a real-life system, and then study that system in either a shorter time frame or for less cost than with the actual system. As a "what-if" analysis tool, Flexsim provides quantitative feedback on a number of proposed solutions to quickly narrow in on the optimum solution. Flexsim's realistic graphical animation and extensive performance reports identify problems and evaluate alternative solutions in a short amount of time (Garrido, 2009). Using Flexsim to model a system before it is built, or to test operating policies before they are actually implemented will avoid many of the pitfalls that are often encountered in the startup of a new system. Improvements that previously took months or years of trial-and-error experimentation to achieve can now be attained in a matter of days and hours using Flexsim.

Garrido (2009) also mentioned that in technical terms, Flexsim is classified as a discrete-event simulation software program. This means that it is used to model systems, which change state at discrete point in time as a result of specific events. Common states might be classifications such as idle, busy, block or down, and some example of events would be the arrival of customer orders, product movement, and machine breakdowns.

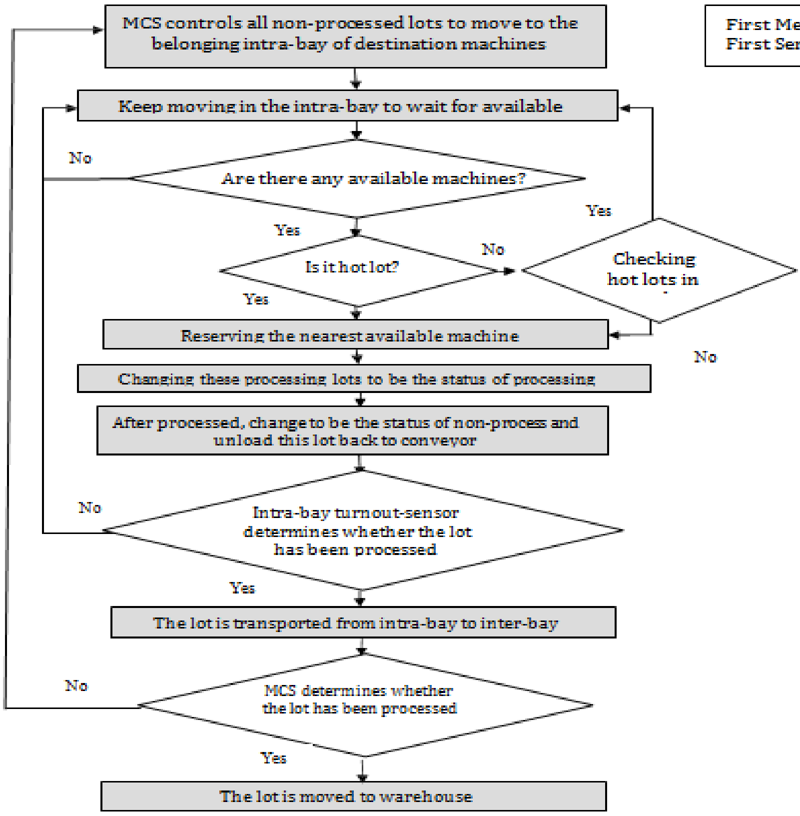


Fig. 7: Conveyor transport rules

The items was processed in a discrete-event simulation model are often physical products, but they might also be customers, paperwork, drawings, tasks, phone calls, electronic messages, etc. These items proceed through a series of processing, queuing and transportation steps in what is termed a process flow. Each step of the process may require one or more resources such as a machine, a conveyor, an operator, a vehicle or a tool of some sort. Some of these resources are stationary and some are mobile, some resources are dedicated to a specific task and others must be shared across multiple tasks.

Flexsim is a versatile tool that has been used to model a variety if systems across a number of different industries (Garrido, 2009). Flexsim is successfully used by small and large companies alike. Roughly half of all Fortune 500 companies are Flexsim clients; including such noted names as General Mills, Daimler Chrysler, Northrop Grumman, Discover Care, DHL, Bechtel, Bose, Michelin, FedEx, Seagate Technologies, Pratt and Whitney, TRW and NASA.

Nordgren (2003) stated that Flexsim is an object-oriented simulation system. It is featured by its hierarchy, inheritance and concurrency. Some built-in objects are provided by Flexsim for easy development. Users can easily modify them into user-defined objects for specific purposes. Table 1 demonstrates some of the objects defined in our simulation model.

3.4. Sequential search algorithm

Introducing sequential algorithm: A search algorithm is a method of locating a specific item in lager collection of data. The sequential search algorithm is a simple technique for searching the contents of an array. The algorithm uses a loop to sequentially step through an array, beginning with the first element. It compares each element with the value being searched for. The sequential search is best used if the array we are searching is unsorted. This method of searching is usually used on small arrays of less than 16 elements. We start the sequential search by first declaring a target to be found. The search initiates at the beginning of the array until it finds the target. In the following example we will find a target value of 23 within a one dimensional array.

At index 0, 32 is not equal to 23 so we proceed on to the next element.

a[0]	a[1]	a[2]	a[3]	a[4]
32	431	-34	23	12

At index 1, 431 is not equal to 23 so we proceed.

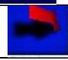
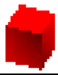
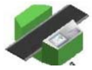
a[0]	a[1]	a[2]	a[3]	a[4]
32	431	-34	23	12

At index 2, -34 is not equal to 23 so we proceed.

a[0]	a[1]	a[2]	a[3]	a[4]
32	431	-34	23	12

Finally at index 3, 23 is equal to 23 and we have found our target.

Table 1: Defined objects in the Flexsim simulation models

Items	Functions	Defined object name
Sources	Input Lots	 Source
Output	Output Lots	 Sink
Warehouse	Store Lots in the Stocker	 Queue
Products	Entity of Products	 Normal lot
		 Hot lot
Equipment	Process Lots	 Processor
Conveyor	Delivery Lot	 Conveyor

a[0]	a[1]	a[2]	a[3]	a[4]
32	431	-34	23	12

Introducing the "For-loop": The statements in the for-loop repeat continuously for a specific number of times. The "while" and do-while loops repeat until a certain condition is met. The for loop repeats until a specific count is met. We use a for-loop when the number of repetition is known, or it can be supplied by the user.

The "For-loop" syntax is as follows:

For (variable initialization; condition; variable update)

{*Code to execute while the condition is true*}

The variable initialization is evaluated before the loop begins. It is acceptable to declare and assign in the variable initialization (such as int x = 1;). This variable initialization is evaluated only once at the beginning of the loop.

The condition will evaluate to TRUE (nonzero) or FALSE (zero). While TRUE, the body of the loop repeats. When the condition becomes FALSE, the looping stops and the program continue with the statement immediately following the for-loop body in the program code.

The variable update executes after each trip through the loop. The variable may increase/decrease by an increment of 1 or of some other value.

3.4.1. Sequential search algorithm coding

Fig. 8 is an example of sequential search algorithm program in this research. The variable initialization of for-loop is set to one, the conditions need the variable initialization is less than or equal to the total number of processes, and the number of closest idle machine to item equal zero. When one of these conditions does not occur, the variable initialization will plus 1. If the state of the detected machine number X is idle or in unloading progress, the number of closest idle machine to item will be X. Otherwise, the total busy machine will plus one. After that, the for-loop will start again with variable initialization plus one and it will determine the condition.

```
{
    Index i;
    For(i=1;and(i<=total number of processes, the number of
closest idle machine to item =0),i++)
    {
        If(detected machine number X state = machine's state
is idle or in unloading progress)
        {
            The number of closest idle machine to item=X;
        }
        Else
        {
            Total busy machine number+1;
        }
```

Fig. 8: Example of sequential search algorithm program

4. Experiment results

4.1. Simulation experiments

To convey our idea on automated materials handling services for hot lots in 450mm wafer fabs, simulation experiments are conducted based on realistic data from a local 300 mm wafer fabs. According to International SEMATECH ISMI 450 mm Guidelines (2009) data show that the processing machine of the size of equipment is similar between 450 mm and 300 mm wafer. This research assumes the 450 mm wafer fab specifications of process equipment is similar with 300 mm wafer fabs.

This simulation models in this study are implemented with Flexsim simulation software (Flexsim 2009), a discrete-event simulation package from Canyon Park Technology Center (1577 North Technology Way, Building A, Suite 2300 Orem, Utah 84097 USA). In the semiconductor fab, the automatic material transporting system is a quite complex system. It is too complex to allow the real simulation situation; therefore, this study tries to simplify the systems under the SEMATECH ISMI 450 mm Guidelines (2009) with the following assumptions:

(1) The data of ISMI 450 mm Guidelines (2009) show that the processing machine of the size of

equipment is similar between 450 mm and 300 mm wafer. This research assumes the 450 mm wafer fab specifications of process equipment is similar with 300 mm wafer fabs.

(2) In this research, we use the material is 450 mm fab, each lot fixedly loads 25 pieces of wafer, the tool process time for every day is 24 hours and 7 days per week, altogether runs 14 days (1209600 seconds). In this simulation experimental AMHS system, there are 69 process tools altogether.

(3) There is a central aisle is 145 foot long among entire test simulation fab. It is equipped with unidirectional track for an inter-bay in the channel. The central aisle connects 5 intra-bays, each intra-bay aisle is 100 foot long.

(4) In the inter-bay and intra-bay are connected with conveyor-curved. The running speed of the conveyor is 4.18 ft/s, which is similar with OHT. The time for each loading/unloading operation of a carrier is 20 seconds.

(5) There are no failures and maintenance activities on the conveyor and equipments during the simulation horizon.

(6) The conveyor operates without the impact of acceleration and deceleration.

(7) The conveyor is continuous flow transport with the same direction.

(8) Since we are interested in the effects on the performance of the conveyor system, the form to relationship between two processing units is adopted, instead of considering the whole process flow of a semiconductor product.

(9) The inter-arrival time of transport requests is probabilistic and is assumed to be of exponential distribution.

(10) In this research, two kinds of product are deployed. The first one is normal lot and the other is hot lot.

In this model, there are one inter-bay loop and five intra-bay loops. The turnout-sensors set in the intersection to determine whether the completion of products. If the products complete, it will be released to next process. Otherwise, it will return to original process.

In this research, observing the dynamics of the Conveyor system, in the experiment design, we consider two dominating control variables bay loading and hot lot ratio.

Systems with heavy loadings are adopted to highlight the effect on the hot lot rules in resource contention. Bay loading is defined as the average number of hourly input lots divided by the maximum number of hourly output of a bay. In the simulation, we used 85%, 90%, and 95% bay loading of the design specification. As the increasing hot lot ratio will impose long time delays on the normal lot drastically. Three hot lot ratios: 2%, 6% and 10% are designed for tests. The hot lot ratio is the average number of hot lot divided by the average number of lots in a bay. Hence, the raw material input quantity = the seconds of an hour ÷ (bottleneck output lots per hours × bay loading percentage × product ratio percentage) (Fig. 9).

Fifteen simulation experiments are then conducted based on the scenarios for these two control variables. The Conveyor delivery time, the time from the birth of a transport job to its completion, is considered as the performance measure. Each experiment is conducted five times. The total number of simulation experiments performed is 3 (hot lots ratio) x 3 (bay loading) x 5 (replication) = 45. The simulation horizon is set to 14 days long with a one day per-run for each experiment.

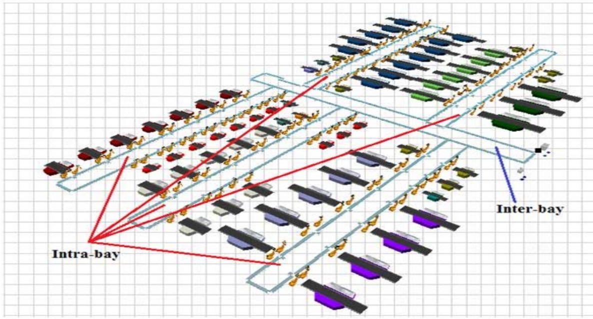


Fig. 9: Simulation model

4.2. Performance Index

In the execution simulation process, the Flexsim system can automatically record the result data. In this research can act according to the material which produces to perform to analyze, discovers reveals the index of performance by using of as the result evaluation. This experimental institute emphatically index of performance is:

Average lot variable delivery time: The average lot variable delivery time and the WIP quantity are related. Average lot delivery time is short to express the WIP resident time is long; This index point out the average lot delivery time influences the WIP quantity and the high WIP expressions production cycle relatively lengthens. Regarding said in the high variation of the semiconductor fab that, the delivery rate is quite disadvantageous.

Average lot variable delivery time= theoretical time + loading and unloading time + product waiting time = fixed time (theoretical moving time, loading and unloading time) + variable time (waiting time).

The fixed time has theoretical value, and it cannot be changed. But waiting time is different. A good method can reduce the waiting time end; therefore, shrink the product delivery time. In addition, it has some several information item of the system, like "the output of product", "the utilization of each tool type" and "idle of conveyor". But in this research take "variable time" from lot delivery time as the main index of performance to demonstrate the efficient result.

4.3. Simulation Results

This research discussed the Conveyor Prioritize Dispatching Method, and compared with the Nearest Job First rule (NJF) from two control variables. The results under different bay loadings are discussed and analyzed. The experimental results are demonstrated on Table 2.

Because the NJF rule does not have the capability to distinguish the movement for lots with different priorities, the results of both hot lots and normal lots are all the same in different configurations (Fig. 10).

Table 2: Experiment results in variable time of the lot delivery time (in second)

System Configuration		Average variable time (in second)		
Bay loading (%)	Hot ratio (%)	CPD		NJF
		Hot lots	Normal lots	Normal lots
85%	2%	16.84	211.60	208.20
	6%	19.57	223.13	208.20
	10%	20.12	242.05	208.20
Average of 85%		18.84	225.59	208.20
90%	2%	20.78	407.70	390.60
	6%	22.72	447.67	390.60
	10%	24.50	483.67	390.60
Average of 90%		22.67	446.35	390.60
95%	2%	33.49	2728.11	2400.69
	6%	36.05	3330.46	2400.69
	10%	40.57	4437.64	2400.69
Average of 95%		36.70	3498.74	2400.69

85% bay loading:

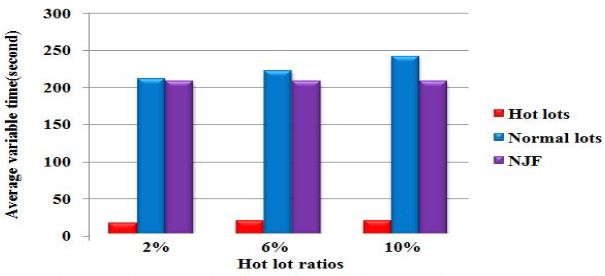


Fig. 10: The average variable time of 85% bay loading

According to Table 2 and Fig. 10, in three hot lot ratios 2%, 6%, 10%, the hot lots average variable time of CPD is lower than NJF. For example, in the hot lot ratio of 2%, the hot lots average variable time is from average 208.20 seconds to average 16.84 seconds. We find that the CPD rule performs significantly different as compared to the NJF rule. In addition, as the increasing hot lots will impose long time delays on the normal lot drastically. CPD reduces the average waiting time of hot lots by 90.95% (from 208.20 seconds to 18.84 seconds) but the normal lots increases the average waiting time is 7.7% (from 208.20seconds to 225.59 seconds) (Fig. 11).

90% bay loading:

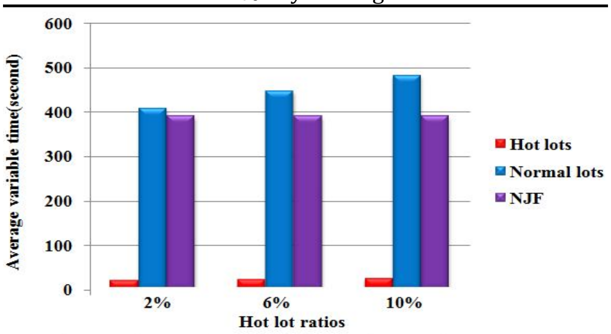


Fig. 11: The average variable time of 90% bay loading

Fig. 11 and Table 2 indicate apparently that in three hot lot ratios 2%, 6%, 10%, the hot lots average variable time of CPD is lower than NJF. For example, in the hot lot ratio of 6%, the hot lots average variable time is from average 390.60 seconds to average 22.72 seconds. We find that the CPD rule performs significantly different as compared to the NJF rule. In addition, as the increasing hot lots will impose long time delays on the normal lot drastically. CPD reduces the average waiting time of hot lots by 94.2% (from 390.60 seconds to 22.67 seconds) but the normal lots increases the average waiting time is about 12.5% (from 390.60 seconds to 446.35 seconds) (Fig. 12).

95% bay loading:

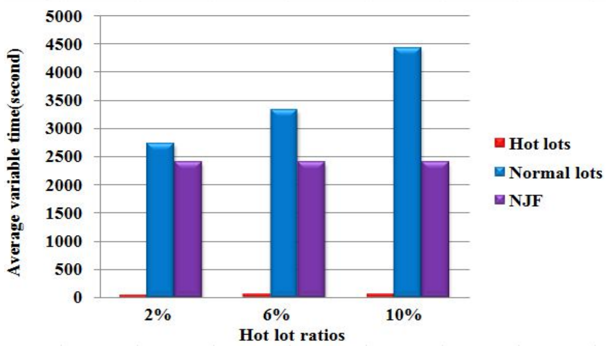


Fig. 12: The average variable time of 95% bay loading

Fig. 12 presents the average variable time of 95% bay loading in three hot lot ratios: 2%, 6%, and 10%. From Figs. 4, 5 and Table 2, it is evident that the hot lots average variable time of CPD is lower than NJF. For example, in the hot lot ratio of 10%, the hot lots average variable time is from average 2400.69 seconds to average 40.57 seconds. We find that the CPD rule performs significantly different as compared to the NJF rule. In addition, as the increasing hot lots will impose long time delays on the normal lot drastically. CPD reduces the average waiting time of hot lots by 98.47% (from 2400.69

seconds to 36.70 seconds) but the normal lots increases the average waiting time is 45.9% (from 2400.69 seconds to 4437.64 seconds) (Fig. 13).

Remarks:

1. "Hot lots" is higher priority product in CPD method. "Normal lots" is lower priority products in CPD method

2. NJF is Nearest Job First.

3. H indicates hot lots ratio, e.g., H0.02 implies 2% of hot lots.

4. L indicates bay loading, e.g., L90 implies 90% loading in the loop.

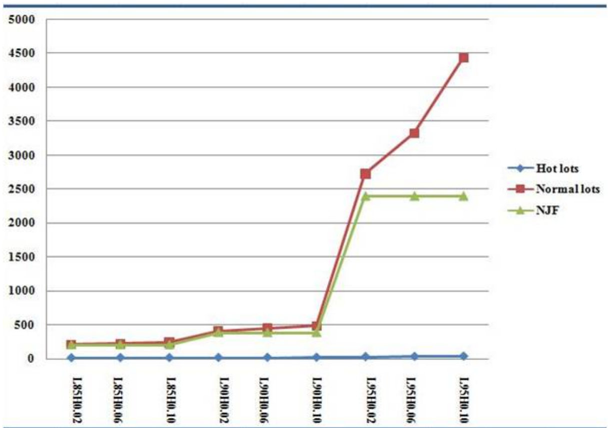


Fig. 13: Simulation average results in different configurations (in seconds)

The simulation results in different configurations shows in Fig. 13. When increasing bay loading or hot lot ratio, each curved trends upward. Under the same bay loading, the hot lots ratio increase will lead the normal lots hot lots average variable time of CPD rise, the hot lots quantity increases will delay more normal lots average variable time.

4.4. Results discussion

This research found the CPD method performs better in reducing hot lots average variable delivery time. The CPD method reduces average variable time of hot lots by 90.95% (from 208.20 seconds to 18.84 seconds), 94.2% (from 390.60 seconds to 22.67 seconds), and 98.47% (from 2400.69 seconds to 36.70 seconds) for 85%, 90%, and 95% bay loading respectively. Compared with the NJF rules, the CPD reduces the average variable delivery time of hot lots by 94.54% and increases the average variable delivery time of normal lots by 22.03%. We can indicate that the average variable delivery time of hot lots is reduced significantly. The results coincide with our expectations. The simulation experiments show that the CPD is a good method to reduce the delivery time of prioritizes products in a 450 mm wafer foundry environment.

5. Conclusion

5.1. Research conclusions

With the increase in wafer size, wafer manufacturing equipment has become increasingly large. As a result, highly automated material handling has become an inevitable trend, but this also increases the complexity of control operations. The focus of this study is to help foundries avoid additional investment and make transportation systems more efficient. A higher priority job should enjoy greater transportation privileges than those with a lower priority. The critical problem is how to provide a nearly no-wait transport for hot lots in an automatic material handling environment.

In modern technology, the CPD rule is a good method in AMHS; therefore, it serves as a benchmark comparison in this study. Based on empirical data, and considering the effect and limitations of transportation in 300mm wafer fab when applying in 450 mm wafer, this research proposes a Conveyor Prioritize Dispatching rule (CPD) to minimize the transport time of hot lots with least impacts to the delivery of normal lots, and compared with Liao and Fu (2002) NJF rule in 450 mm wafer manufacturing. The results demonstrate CPD rule hot lots average variable time reduced by 94.54% (from 2400.69 seconds to 16.84 seconds).

This simulation experiments are based on same simulation time and gives in different system configuration of bay loading and hot lots ratio. The result shows the CPD has the shorter variable time of hot lot but a little longer variable time of normal lot than NJF. When increasing loading or hot lots ratio, each curve trends upward for hot lots. CPD rule can effectively reduce hot lots of average variable time, but incurs delivery time delays in normal lot.

5.2. Future research direction

Future researches will consider high product mix leads to more frequent process changes, dispatching rule of multi-ranks transport, automatic dispatching rule of Segmented Dual-track Bidirectional Loop (SDBL) and expand simulation model to a full-scale AMHS application. Future researches will also consider CPD method with different speeds in 450 mm wafer. In the future, it can conform to transmit demand for all levels of products and use CPD method as the basis of 450 mm wafer fab in transport policy.

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