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A distance metric for cylindrical semiconductor fabrication facilities

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Abstract: Many endeavors at the design of future semiconductor fabrication facilities have envisioned them as being cylindrical in shape. The idea being that the closer one is to the center of the building, the "cleaner" the room is. The core of the building has been envisioned as a shaft in a vacuum containing nothing but robotic material handling systems transporting wafers around and between floors. This research builds upon this idea and delineates a new distance metric, entitled herein as the "recta-polar" metric, for evaluating different semiconductor fabrication facility layouts within the material flow movement constraints and confines of the cylindrically shaped fabrication facility.

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1. Introduction

Semiconductor fabrication facilities, also known as "fabs", of the future have been envisioned as cylindrical in design. This "wafer silo" design is depicted in Figure 1. The reasoning behind the shape of this design is based upon the requirements of *manufacturing wafers* rather than the requirements of humans within the fab [1]. In other words, this idea stems from designing the fab itself as a precision machine. This silo design includes the ability to designate the cleanliness of any particular "bay" or "chase" based upon its location relative to the center of the building.

As depicted in Figure 1, the wafer silo future fabs are premised on containing three basic areas. For this study, these areas are labeled as the core area, the inner areas, and the outer areas.

The core area is envisioned as a Class 0.01 (immeasurable with today's technology) clean room space where no humans enter. It is seen as a space where hermetically sealed boxes (pods) of wafers travel via a system of redundant robotic material handling systems (not the subject of this treatise) between floors and the inner area bays.

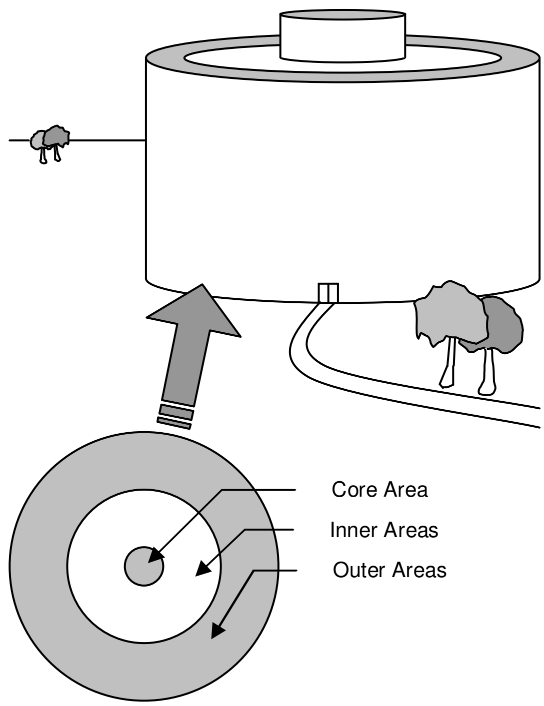

Figure 1. Wafer Silo Fab

The inner areas shown in the fab in Figure 1 are foreseen as containing (approximately) the Class 0.01 to Class 1 clean rooms. These rooms would be in the shape of a "polar wedge." The general shapes of these polar wedges are shown in Figure 2 below.

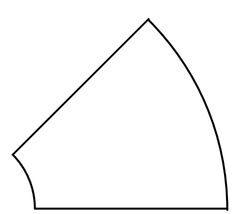

Figure 2. Polar Wedge Shape

This shape also applies to the outer areas depicted in Figure 1, which are reserved for Class 10 and above clean rooms (dicing, chip mounting, wire-bonding, package sealing, etc.) as well as office areas and other *human* centered spaces.

This idea is centered on the ability to control the laminar flow of air from the HEPA-Filters. Areas closer to the core would have a higher air pressure. In addition, systems (possibly air locks) are assumed to be in place to minimize the amount of pressure loss (air flow) between different areas when people and/or material travels between them. This idea is further supported by the fact that the circle is the shape that produces the maximal area in relation to its circumference.

2. Background

To wit, no such study on distance metrics (or distance measures, norms, gauges, etcetera) for wafer silo fabs (or similarly shaped facilities, distribution centers, warehouses, etcetera) has been written in the available literature.

The various layouts that can be constructed within this basic shape parameter are complex. The purpose of this study is to present a class of distance metrics that can be used to compare different layouts. The purpose here is *not* to propose facility layout construction or facility layout improvement techniques. Instead, it is to provide an analysis tool for the facility planner to compare different alternatives that have been arrived at. How the various layouts were arrived at are (again, self admittedly) beyond the scope of this treatise.

3. Material Flow

A note must be made about the flow of material (WIP wafers) within the facility itself. Since the inner areas are cleaner than the outer areas, it is stipulated that once material moves into a cleaner area it never leaves the cleaner area. That is to say, until actual chips are ready to leave the building, wafers are processed in a fashion that moves them closer to the core with consecutive processing.

This study will concentrate on three levels of cleanliness: the core area, the inner areas, and the outer areas. This model will facilitate the development of the distance metric, which, in turn, can be generalized to include more levels.

It is envisioned that in between the different areas are hallways. These hallways encircle the various areas. These hallways are analogous to the hallways now found in the typical "spinal" layouts for semiconductor fabrication facilities. It is envisioned that it is inside the core and these hallways where the inter-bay material handling will take place. Material that leaves a particular bay will travel around the fab either in the core (for more advanced wafers) or along one of the circular hallways.

Furthermore, when material needs to move from one polar wedge shaped bay to another, it will move in one of two ways. In process wafers will either make an intra-area (staying within the same annulus shaped area) move or it will move from the (an) outer area to the (a more) inner area (an inter-area move).

Distance Metric:

It is known that any function g: $\mathcal{R}^N \rightarrow \mathcal{R}^1$ which satisfies the following is called a norm [2].

1. $g(x) \geq 0, \forall x \in \mathcal{R}^N$
2. $g(x) = 0 \leftrightarrow x = 0$
3. $g(cx) = |c| g(x), \forall x \in \mathcal{R}^N, c \in \mathcal{R}^1$
4. $g(x) + g(y) \geq g(x+y), \forall x, y \in \mathcal{R}^N$

Note that the third property above implies symmetry: $g(x) = g(-x)$. The fourth property (triangle inequality) ensures that the shortest route between points is always taken. In actual practice, the inter-bay material handling systems may have other physical constraints or operating characteristics (e.g., one-way travel), but for evaluation of facility layouts, we will assume that shortest route is always available. These four properties also help define a distance metric.

For the wafer silo model portrayed herein, the new metric is delineated as follows. As noted above, in process wafers can make one of two moves: intra-area moves and inter-area moves. These two different types of material flows are depicted in Figure 3 below.

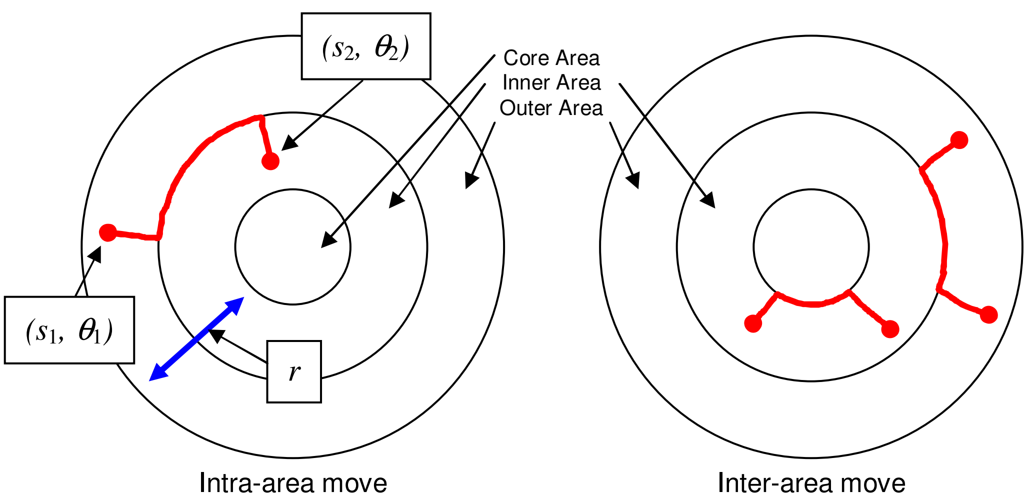

Figure 3. Two basic types of material flows

These two types of moves, when analyzed as a distance are quite similar. The intra-area move involves a radial move followed by an arc shape move and is terminated with a radial move. The same three moves are involved for inter-area material moves as well. The only difference between the two types of moves is the location of the radial moves. However, within polar coordinates both distances can be generalized into one distance metric. This distance metric, $d(\cdot)$, is as follows.

$$d((s_1,\theta_1),(s_2,\theta_2)) = (|s_1 - r| + |r - s_2| + r\min(|\theta_1 - \theta_2|, 2\pi - |\theta_1 - \theta_2|)) \qquad (1)$$

where r is the radius of the hallway or core area used for inter-bay travel, s_1 and s_2 are the radial polar coordinate components of the move under investigation, and θ_1 and θ_2 are the angular polar coordinate components of the of the move under investigation. The “min” function on the arc travel component of the metric is necessary to ensure that the triangle inequality holds.

The metric in (1) is coined herein as the *recta-polar* distance metric. It is named thus because the two major components of travel (radial and arc-wise) involved are separable. This is similar to the rectilinear metric in two dimensions. Indeed, it has been postulated that entire sections of the building could *rotate* in an effort to minimize the sum of the arc-wise material handling times over some planning horizon.

4. Conclusions

A short note for a new distance metric for determining wafer travel distances between points in a wafer silo shaped fab has been presented. It is hoped that this small treatise can be a catalyst to other research in the area of semiconductor fabrication facility layouts of the future.

References

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