Airflow in the 300mm Semiconductor Factory

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Abstract

Based on field experience with advanced 200mm wafer fabs, the author discusses the conversion to 300mm fabs and related airflow issues. Increased tool placement and efficiency combined with automated transport systems and standard mechanical interfaces decrease the risk of airborne contaminants in the fab effecting work in progress. Long held beliefs regarding airflow velocity, parallelism and pressurization in the semiconductor manufacturing cleanroom are examined.

Introduction

Airflow in the cleanroom is used primarily to control contamination while maintaining temperature and humidity. The air is filtered and recirculated with a nominal amount of outside air introduced to maintain proper room pressurization by compensating for air lost through exfiltration and process exhaust; additionally, the outside air introduced into the cleanroom ensures a safe environment for the equipment operators and maintenance personnel.

Much of the new 300mm fab will have process tools contained within their own environments capable of controlling airborne particulates along with temperature and humidity. These mini-environments will have standard mechanical interface (SMIF) loading ports served by automated transport systems handling sealed wafer carriers. The chance of fab airborne particulates contaminating the wafer surface will be significantly reduced and perhaps eliminated.

Along with the transition from 200mm to 300mm fabs, the existing Federal Standards 209E, Ref [1], regulation regarding airborne cleanliness is being replaced with the International Standard ISO-14644-1, Ref [3]. The new ISO classifications are referenced in this article.

Airflow Velocity

Filtered laminar airflow within the ISO Class 3 (FS-209E Class 1) cleanroom was traditionally designed for a velocity of 0.45 m/s (90 fpm) resulting in 600 air changes per hour when a 2.7m (9′) elevation existed between raised floor and HEPA filtered ceiling. Over time, efforts to reduce construction costs and energy conservation retrofits have led to today's 200mm ISO Class 3 fab operating with reduced air changes and airflows averaging 0.35 m/s (70 fpm).

Because air inside the 300mm minienvironment will be maintained at ISO Class 2 (FS-209E Class 0.1) or better, fabs implementing fully automatic wafer transport systems may now operate the cleanroom surrounding the mini-environment at cleanliness levels up to ISO Class 6 (FS-209E Class 1,000). This presents an opportunity to reduce average room velocities to 0.30 m/s (60 fpm) or less with ceiling HEPA filter coverage of 80% or less.

Areas of the 300mm fab where work in progress may still be exposed to the cleanroom environment will, however, need to be cleaner than ever from airborne and molecular contamination. In this case, HEPA filtered ceilings will need to remain at 100% coverage with average room velocities of 0.30 m/s or higher and good laminar airflow.

Airflow Uniformity

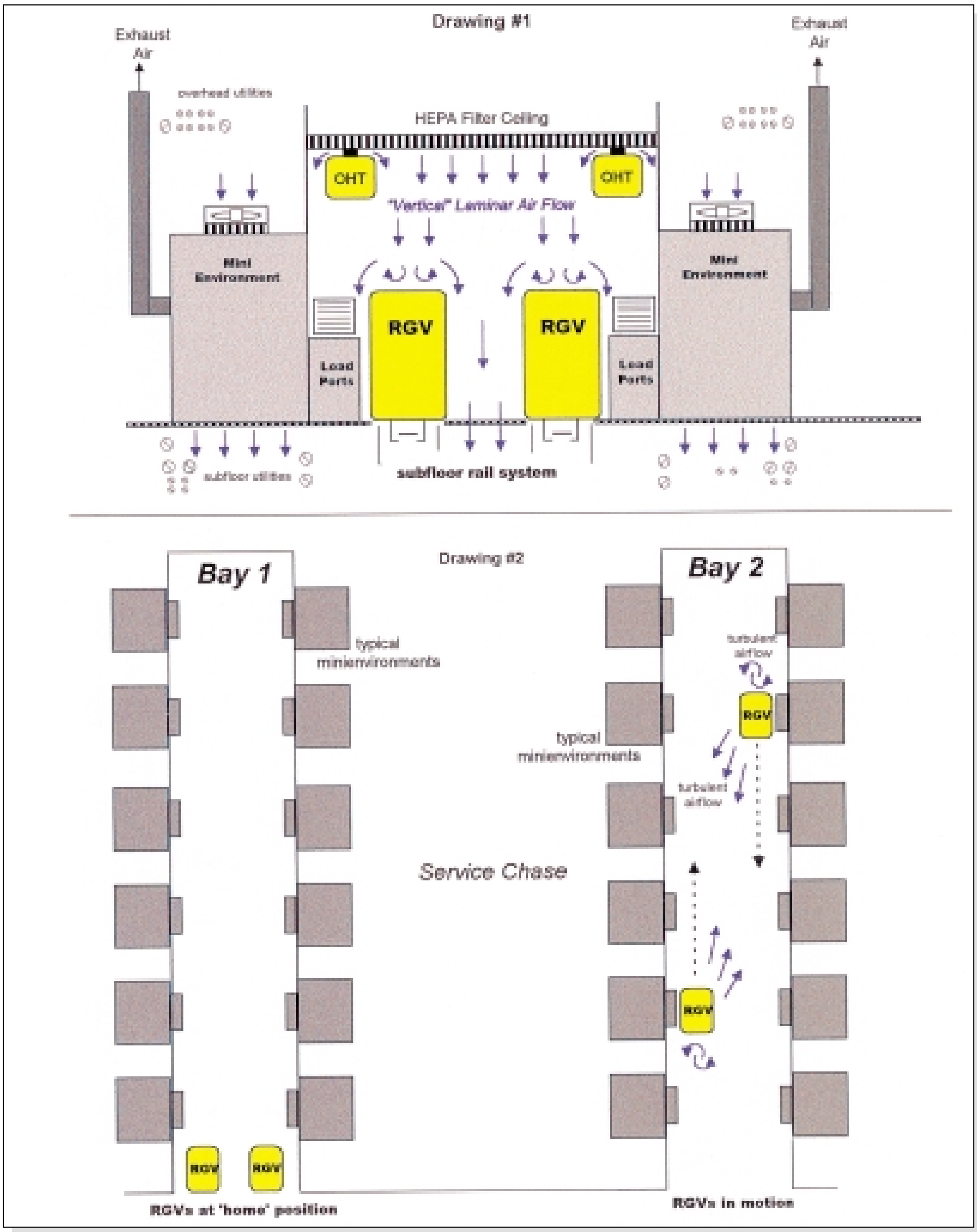
A number of 200mm fabs specify velocity uniformity to be within ± 5% of the average velocity measured in the clean zone, although this is almost impossible to achieve in an operating fab. The author has tested areas of many ISO Class 3 cleanrooms with a velocity uniformity of ± 20% with no apparent impact on product yields.

It is the author's opinion that requiring the new 300mm fabs with their sealed wafer carriers and self contained mini-environments to have a uniformity of better than ± 20% of the average room velocity does not justify the investment and will only serve to extend fab startup time.

Room Pressurization

The cleanest zones in a fab must operate at a slightly higher pressure than surrounding less clean zones to prevent contamination from entering the cleaner zone; this means an ISO Class 1 area operates at a higher pressure than an ISO Class 2 area which operates at a higher pressure than an ISO Class 3 area, and so on.

For the most part, proper room pressurization is achieved by balancing the outside air introduced with



Above Top – Figure 1. Interruption of vertical Laminar flow by robot rail systems. Above Bottom – Figure 2. Turbulent airflow caused by automatic and rail guided vehicles within a processing bay

process air exhausted from the clean zone. When available, dampers in the raised floor system are sometimes used to adjust room pressures, although it is preferable to use these floor dampers when fine tuning vertical laminar airflow within the clean zone.

Airflow exfiltration at gowning rooms and equipment staging areas along with all perimeter doors serving the cleanroom is expected and additional outside air must be introduced to make up for these losses. Sources of unexpected exfiltration such as poorly sealed utility penetrations and clean zone barrier walls should be located and controlled.

The mini-environment used in a bay and chase type cleanroom is more susceptible to fab airborne contamination than a mini-environment located in a ballroom type cleanroom due to the pressure differences of the bay and chase exerting themselves on the process and service sides of the mini-environment.

When the service chase is used as an upflow return air path, pressure differences ranging from 0.025 kPa to 0.050 kPa (0.10”wg - 0.20”wg) and larger frequently exist. The mini-environment is an integral part of the bay and chase wall system and as such it must be pressurized to counter the effects of the two different air pressures at its process and service sides. These air pressures undergo subtle and not so subtle changes on a daily basis. Many mini-environments in existing 200mm fabs experience contamination problems during their service life due to these circumstances.

When HEPA filtered downflow air is supplied to the service chase, pressure differences of as little as 0.003 kPa (0.01"wg) between the process bay and service chase are all that is necessary to maintain cleanliness classes between the bay and chase. Even with these low pressure differences, it is possible for a well built mini-environment to experience contamination problems due to the two different air pressures at its process and service sides.

UNIDIRECTIONAL AIRFLOW

Unidirectional airflow, referred to as parallelism or laminarity, is the laminar movement of air in a cleanroom and is necessary to limit the dispersion of internally generated contamination. Good vertical laminar airflow has traditionally been limited to no more than 14° offset from true vertical.

Laminarity is primarily affected by the pathway air must follow after it passes through the raised floor system. For example, does it flow straight through a perforated slab into a sub-fab area to be returned to the fan deck or does it flow under the process tools and up through the service core to be returned ? Both designs have their advantages, but it's much more difficult to achieve and maintain good laminar airflow when the latter occurs. Laminar airflow is also affected by the airtight integrity of walls separating the various clean zones within the cleanroom.

The horizontal movement of relatively large intra-bay robots, inter-bay automatic and rail guided vehicles, along with overhead track systems serving the entire fab has significantly compromised the ability of the clean room to maintain vertical laminar airflow; see Figures 1 and 2.

CONCLUSION

Activities such as field measurement of airflow velocity and laminarity in the process side of the operating 300mm cleanroom will have to be reduced to avoid the possibility of damaging wafer carriers containing twenty-five wafers valued at up to $1,000,000(US) and more. The author has experienced very anxious moments when a wafer carrier containing thirteen 200mm wafers unexpectedly passes by on an overhead track system while he is measuring airflow nearby.

Present safety interlocks, such as exhaust static pressure indicators at the process tool which interrupt production when variations in system static pressure are sensed, will have to be reconfigured to ensure uninterrupted production time while maintaining product and operator safety.

Emergency shut off buttons (EMOs) at each tool will have to be ergonomically designed to avoid accidental interruption of production. Hardly a day goes by in the industry without some process tool being shut down due to someone accidentally brushing against an EMO button, and the risk continues to increase as tool installation is maximized per factory footprint.

A major shift from traditional methods of designing, building and operating the ventilation systems serving a semiconductor IC manufacturing fab will have to occur. From the planning stage to tool installation and hookup, more attention must be spent on the airflow path as it enters the cleanroom, passes through the raised floor and returns to the fan deck.

REFERENCES

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[2] IES-RP-CC006.2
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[3] International Standard ISO DIS 14644-1
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[4] I300I Factory Guidelines: Version 2.0
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[4] Asyst Technologies SMIF-300FL™ Evaluation
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ABOUT THE AUTHOR

Bill Carr has been testing cleanroom environments since 1970. He is president of US Test & Balance Corporation and certified by the National Environmental Balancing Bureau (NEBB) and the Testing, Adjusting and Balancing Bureau (TABB).

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