# Design of local exhaust ventilation for preventive maintenance in the semiconductor industry using CFD


Jwaryung Hong[1], Jae-Han Koo[2], Chang-sup Park[2], Hyunhee Jung[1], Soojin Lee[3], Kwang-min Choi[1]

[1]Samsung Health Research Institute, Samsung Electronics Co. Ltd., [2]Environment Safety Health Group, Semiconductor R&D Center, Samsung Electronics Co. Ltd., [3]Department of Occupational and Environmental Medicine, Hanyang University, Republic of Korea


## 1. Background

- When the chemicals are remained or generated by-product in equipment, which causes defects the product thus maintenance tasks are necessary periodically
- The maintenance tasks are performed manually by workers
  - Replacement parts, troubleshooting and wiping out a chamber with an ethanol or de-ionized water soaked wiper
- At this time, there are potential risks that the maintenance workers might be exposed the reactant or by-products during the work. Additionally, the contaminants are released which may disperse in cleanroom, so workers who work surrounding area might be exposed as well [1, 2]

## 2. Objectives

- Design local exhaust ventilation(LEV) for maintenance tasks in order to improve working environment and protect worker's health in semiconductor manufacturing process
- The primary focus in designing the hood was convenience and un-disturbance of the work

## 3. Methods

1) Experimental and numerical Model

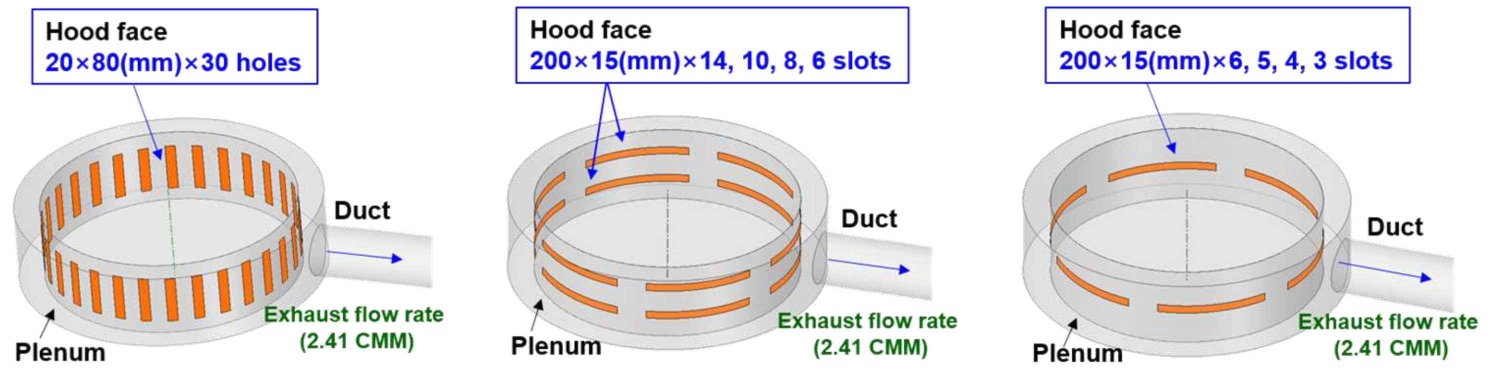
- 300 mm semiconductor wafer fabrication facility, ISO class 5 (South Korea)
- Metallization process chamber was used
  - A cylindrical chamber : 600(d) x 100(h) mm


(a) PM operation of Metal chamber

(b) Circular hood with slot faces

Figure 1. Metallization process chamber and test hood

- LEV : A cylindrical shape (same size with the chamber, D = 600 mm)
  - To place on the chamber
    : Control the contaminants before disperse out of chamber
  - The circular hood was made of acrylic were used in the experiments
  - The measurements of face velocity
    : Hot-wire anemometer (TSI 9515) at 30 distributed points




(a) Case 1: Rectangular type | (b) Case 2~5: Slot type (2 layers) | (c) Case 6~10: Slot type (1 layer)

2) Numerical method

- The commercial code : Fluent Ver. 19.2 (Ansys Inc.)
- Turbulence model : realizable k-ε model
- SIMPLE(Semi-Implicit Method for Pressure Linked Equations) algorithm

3) Boundary conditions

- Flow rate : 2.41 $m^3$/min
- Capture efficiency (CE) = $(1-M_{out}/M_g) \times 100(\%)$
  $M_g$ : the contaminants amount
  $M_{out}$ : the amount of dispersion to outside
  - The ratio of the captured contaminants to the total generated emission rate
  - Source : A metalloid that is a member of group 15 of the periodic table
    → uniformly released from a bottom of the chamber
- Mesh : 550,000~1,000,00

Table 1. Types and conditions of numerical analysis

| Case | Type | Hood face number | Layer | Opening Dimensions | | Flow rate ($m^3$/min) |
|---|---|---|---|---|---|---|
| | | | | W x L (mm) | Area($m^2$) | |
| Case 1 | Rectangle | 30 | 1 | 80 x 20 | 0.048 | 2.41 |
| Case 2 | Slot | 14 | 2 | 20 x 200 | 0.048 | |
| Case 3 | Slot | 10 | 2 | 20 x 200 | 0.040 | |
| Case 4 | Slot | 8 | 2 | 20 x 200 | 0.032 | |
| Case 5 | Slot | 6 | 2 | 20 x 200 | 0.024 | |
| Case 6 | Slot | 6 | 1 | 20 x 200 | 0.024 | |
| Case 7 | Slot | 5 | 1 | 20 x 200 | 0.020 | |
| Case 8 | Slot | 4 | 1 | 20 x 200 | 0.016 | |
| Case 9 | Slot | 3 | 1 | 20 x 200 | 0.012 | |
| Case 10 | Slot | 3 | 1 | 20 x 200 | 0.012 | |

## 4. Results

1) Comparison to numerical analysis and experimental results

- Overall simulation results agree quite well with the experiments data of measurement to the center line velocity on circular plenum surface
  - The accuracy within 300 mm of the duct opening matched the experimental value within 20%

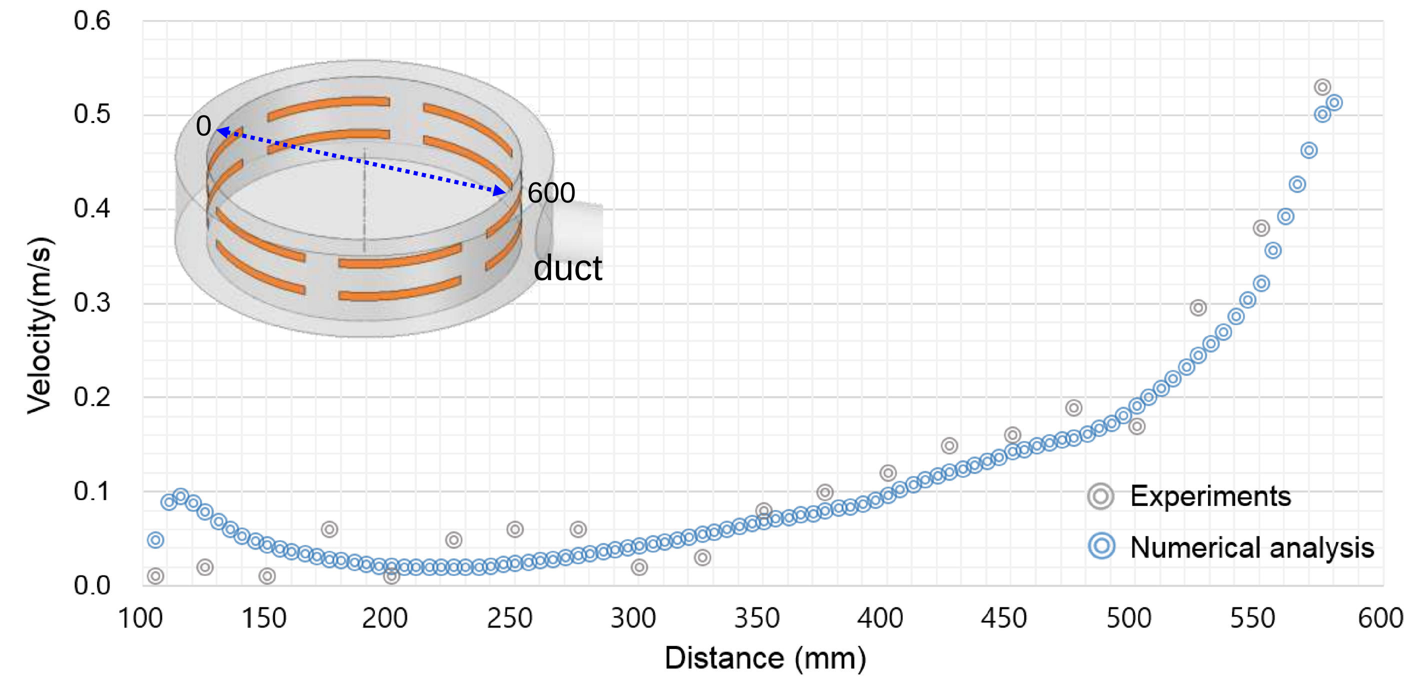
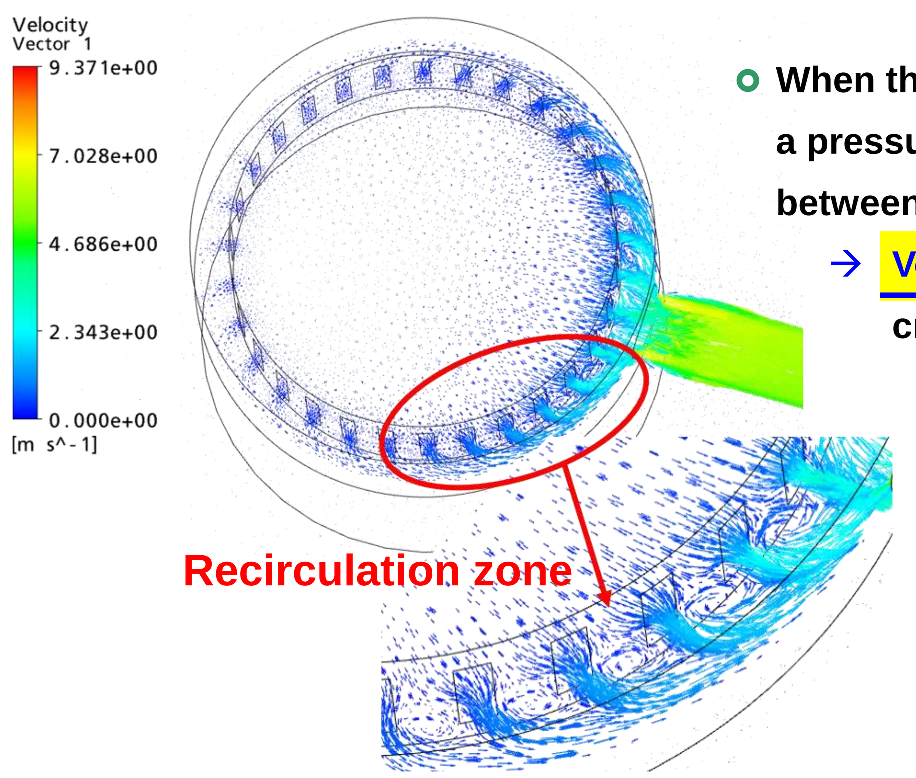



Figure 2. Comparison of the numerical and experimental results

2) Rectangular type opening

- The velocity of each hood face was different by location
  - The speed in the vicinity of the duct opening was up to 2.61 m/s, on the contrary, the minimum velocity opposite the duct opening was 0.12 m/s
    : The ratio of maximum and minimum velocity was 22.7




- When the indraft at the hood face in plenum, a pressure gradient and shear stress between the mixed layer
  → Vortices and recirculation zone were created

For the higher velocity, the greater the flow separation the larger the vortices, which decrease hood control effectiveness

- A stagnation zone might occur at the vortex of the recirculation zone
  - It affects the hood performance and accumulates of pollutant in recirculation zone

3) Slot type opening

- The velocity distribution and capture efficiency were improved than rectangle face
  - Case 1 and 2 have a same area but they are significantly different
    : No recirculation zone in slot type and uniform air flow generated
    : Almost hood face velocity exceeded 0.5 m/s
- Efficiency to the number of slot
  - When the number of slot decreased, the face velocity were improved and uniformity were advanced
  - Case 5 and 6 (different layer with same area)
    : there were no significant differences in slot layer
    : when the 1 layer, the velocity exceeded 2.0 m/s (ratio of maximum and minimum velocity was not more than twice)

Table 2. Results of the simulation

| Case | Type | Hood face number | Layer | Capture efficiency(%) | Mean velocity (m/s) | Velocity distribution (max/min) |
|---|---|---|---|---|---|---|
| Case 1 | Rectangle | 30 | 1 | 82.1% | 0.816 | 22.65 |
| Case 2 | Slot | 14 | 2 | 90.2% | 1.185 | 6.08 |
| Case 3 | Slot | 10 | 2 | 91.8% | 1.401 | 3.80 |
| Case 4 | Slot | 8 | 2 | 93.0% | 1.795 | 2.92 |
| Case 5 | Slot | 6 | 2 | 94.9% | 2.420 | 1.96 |
| Case 6 | Slot | 6 | 1 | 91.1% | 2.366 | 1.57 |
| Case 7 | Slot | 5 | 1 | 92.3% | 2.859 | 1.36 |
| Case 8 | Slot | 4 | 1 | 94.0% | 3.571 | 1.26 |
| Case 9 | Slot | 3 | 1 | 96.3% | 4.802 | 1.27 |
| Case 10 | Slot | 3 | 1 | 96.0% | 4.784 | 1.11 |

## 5. Conclusions

- Slot hood had a higher capture efficiency than a rectangular hood
  - The slot hood provided uniform air flow and higher face velocity
    : There were no vortex in the plenum for slot, that is why slot had better efficiency than rectangular even though they had same face area
- The number of slot
  - the smaller the number of hood face, the higher the velocity and the efficiency
- When the face velocity is maintained more than 1.0 m/s,
  → the capture efficiency is above 90%

## 6. References


1. Chine, C.L., C.J. Tsai, K.W. Ku, and S.N. Li: Ventilation control of air pollutant during preventive maintenance of a metal etcher in semiconductor industry. *Aerosol Air Qual Res.* 7(4):469-488 (2007).
2. Choi, K.M., H.C. An, and K.S. Kim: Identifying the hazard characteristics of powder byproducts generated from semiconductor fabrication processes. *J. Occup. Environ. Hyg.* 12(2):114-122 (2015).





jr1022.hong@samsung.com