Material Issue

Air Pollution Control

Strategies

Best Available Technology (BAT)
Using BAT to deal with operational pollution and reduce its environmental impact

Zero Failure of Control Equipment
Use backup systems and dual-track management to ensure normal operation of control equipment and prevent abnormal events

TSMC 2020/2025 Goals

To decrease air pollutant emissions per unit product by 27%, compared to 2015 level Note 2020
To decrease air pollutant emissions per unit product by 30%, compared to 2015 level Note 2025

Reportable incidents to governing authority <1 2020

Note: Currently, the average reduction rate of volatile organic gases in each factory area has reached more than 95%. Because the expected target for 2020 was reached ahead of schedule, therefore it has been amended to pursue an even higher goal for air pollution prevention and control.
Our Business

Focus One
Ethical Management

Focus Two
Innovation and Service

Focus Three
Responsible Supply Chain

Focus Four
Green Manufacturing

Focus Five
Inclusive Workplace

Focus Six
Common Good

Appendix

2017 Achievements

96.4%
Reduction rate of volatile organic gases was 96.4%

Target: >90%

To decrease air pollutant emissions per unit product by 25%, compared to 2015 level

Note: Air pollutants include a total of 8 chemicals: total hydrocarbons, sulfuric acid, hydrochloric acid, nitric acid, hydrofluoric acid, phosphoric acid, chlorine and ammonia.
The air pollution brought about by the semiconductor manufacturing industry is composed mainly of volatile organic compounds, as well as acidic and alkaline gases. In the field of pollution prevention and control, TSMC adopts the best available technology of source separation and multiple processing to deal with air pollutants effectively, so that when they are discharged in the atmosphere, they meet or surpass government regulations. Moreover, in order to maintain the effectiveness of control equipment and the discharge of pollutants, equipment is supplied with real-time monitoring systems and an N+1 backup system. The relevant monitoring results are transmitted to the facility monitor control system room and the industrial safety emergency response center simultaneously to ensure that air pollutants are treated appropriately when the system is not running normally.

Best Available Technology

TSMC has spared no effort to reduce air pollution. In order to achieve the best available technology in the prevention and control process, TSMC has adopted the method of "effective reduction of exhaust sources and enhanced treatment of terminal control equipment". In the first stage, high-efficiency air treatment equipment (local scrubber) will be installed to treat specific acid-alkaline process exhaust materials, which are toxic, corrosive, flammable or greenhouse perfluorinated compounds depending on their process characteristics. Special equipment such as combustion, plasma, or other types of equipment will treat the remaining process exhaust gas. Finally, the exhaust gas, left with trace amounts of inorganic acids and alkalis, is sent to the central processing equipment (central scrubber) for second-stage water rinsing and neutralization treatment. Two-stage processing and multi-stage treatment can improve the efficiency of air emission treatment.

For organic exhaust, the highly efficient Zeolite Rotor Concentrator is used to concentrate pollutants and then introduced into a regenerative thermal oxidizer to be burned before being discharged into the atmosphere. The reduction rate of organic emissions gas by the regenerative thermal oxidizer (RTO) alone can reach 95%, exceeding the 90% specified by regulations. If first stage site-based processing equipment is included, the total organic emission gas reduction rate can reach above 99%.

Note: Calculation of total reduction rate after two-stage control equipment: $1 - (1 - \text{Local scrubber reduction rate}) \times (1 - \text{Central scrubber reduction rate})$
Effective Elimination of Exhaust Source – Local Scrubbers

TSMC classifies high-concentration exhaust gas into seven categories for in-site treatment according to pollutant characteristics. These are then treated by one of, seven different local scrubbers, including thermal type, burning type, plasma type, washing and dosing type, adsorption type, condensation type, and washing type. Third-party certification has verified that the reduction of target pollutants by in-site air pollution treatment equipment can reach more than 95%. At present, the proportion of advanced process products continues to increase and TSMC will continue to cooperate with supplier partners for the introduction of new local scrubbers for different pollutants so as to enhance the total reduction of pollutants.

Terminal Control Equipment Enhanced Processing – Highly-efficient Central Processing Equipment

After the first phase of emission gas treatment, which consists of low concentrations of inorganic acid and alkali components, it is sent to a two-stage scrubber for neutralization; in the case of volatile organic components, it is sent to the Zeolite Rotor Concentrator terminal control equipment for concentrating, burning and then is discharged into the atmosphere. In 2017, the average reduction rate of volatile organic gas by TSMC’s Zeolite Rotor Concentrator was 96.4%, which was significantly above the 90% required by regulations.

In addition to embracing the most advanced and suitable pollution reduction technology, TSMC has continuously improved the effectiveness of its existing pollution control facilities. Under these enhancement measures, in 2017 the emission per unit product from TSMC was 0.3 (g/8-inch e wafer-layer) compared to 0.4 (g/8-inch e wafer-layer) in 2015, a decrease of 24%. The Company expects its target objective of 30% can be achieved in 2025. Based on actual test results over the years, the concentration of air pollutants emitted by TSMC is lower than the emission standards set by the Science Park Administration and the domestic Environmental Protection Bureau.
Zero Failure of Control Equipment

TSMC's air pollution control capability complies with Taiwan's "Air Pollution Control and Emission Standards for Semiconductor Manufacturing" and the "Air Pollutants Emission Standards for Fixed Pollutants", and overseas subsidiary companies also meet local regulatory standards. To ensure stable 24-hour and 365-day operation of pollution control equipment, all equipment is provided with at least one set of backup systems (N + 1 design). In addition, TSMC has also established automatic monitoring systems to grasp the effectiveness of the exhaust gas treatment at all times. Relevant information is provided to the facility monitor control center and the industrial safety emergency response center at the same time, so gas emissions are tracked under a dual-track independent monitoring system, ensuring that chimney exhaust gas is in compliance with specifications. Under the control of early warning systems and immediate response, there were no unusual events that required TSMC to inform relevant authorities in 2017.

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Annual Emission Reduction Rates of Volatile Organic Gases from Central Processing Facilities

<table>
<thead>
<tr>
<th>Year</th>
<th>TSMC</th>
<th>Subsidiaries</th>
<th>All</th>
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<tbody>
<tr>
<td>2013</td>
<td>94.9</td>
<td>93.1</td>
<td></td>
</tr>
<tr>
<td>2014</td>
<td>95.0</td>
<td>93.5</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>95.3</td>
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<td>2016</td>
<td>95.5</td>
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<tr>
<td>2017</td>
<td>96.5</td>
<td>95.9</td>
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Annual Emissions of Air Pollutants and Emissions Per Unit Product

<table>
<thead>
<tr>
<th>Year</th>
<th>THC</th>
<th>NH₃</th>
<th>Cl₂</th>
<th>HF</th>
<th>HNO₃</th>
<th>HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
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<td>2017</td>
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</tbody>
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Note: Annual emission reduction rates of volatile organic gases in TSMC includes TSMC (included in all wafer fabs and packaging and testing plants in Taiwan) and subsidiary company (included in WaferTech, TSMC (China) and VisEra). VisEra taken into account in 2017.

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Note 1: The air pollutants emissions in TSMC refer to the total amount of emissions reported to the governing authority, including in all wafer fabs and packaging and testing plants in Taiwan. Subsidiary companies (WaferTech, TSMC (China) and VisEra) were not included due to the different items declaration.

Note 2: Total air pollutant emission includes total hydrocarbons (THC), sulfuric acid (H₂SO₄), hydrochloric acid (HCl), nitric acid (HNO₃), hydrofluoric acid (HF), phosphoric acid (H₃PO₄), chlorine (Cl₂) and ammonia (NH₃), a total of 8 kinds.

Note 3: Air pollutant emissions per unit product in TSMC excludes packaging and testing plants (because they do not have actual wafer output to calculate).
Case Study

Application of Hydro-membrane to Enhance Pollutant Removal Efficiency Up to 47%

In order to improve the performance of air pollution control equipment, TSMC continues to cooperate with supplier partners to introduce the latest technologies. In 2016, “hydro-membrane” technology was installed in the scrubber of Fab 14, Phase 5 in Tainan Science Park. It was found that the removal efficiency of acid and alkaline pollutants can be improved 5-47% depending on their different physical and chemical characteristics. In 2017, the technology was extended to all 12-inch wafer fabs in Taiwan and is expected to be included in the standard design for new sites in 2018. After modularizing the installation mode of the hydro-membrane and changing the membrane material, results from Fab 14 Phases 5, 6, and 7 showed that the sulfuric acid (H₂SO₄) concentration of the scrubber was reduced up to 47%. The removal efficiency of other acid and alkaline pollutants can also be improved up to about 5-38%.

Note: “Hydro-membrane” is a slight hydrophilic filler made of monofilament, the main material being polyamide fiber (nylon). The design principle is mainly to transfer mass with larger specific surface area. Compared with the traditional Raschig Ring, the “hydro-membrane” has a larger surface area making it easier for pollutants to come in contact with the “hydro-membrane” and dissolve. In addition, the material is woven into a V-shaped system, by which the circulating water droplets fall into single filaments and immediately collide with another filament, creating a new liquid membrane, increasing the contact efficiency and enhancing the reduction effect of acid and alkaline gas pollutants.

Improvement and Evolution of TSMC Air Pollution Control Equipment

<table>
<thead>
<tr>
<th>Year</th>
<th>Local Air Treatment Equipment</th>
<th>Central Processing Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>Add scrubbers in facility chemical tank</td>
<td>Add 1st. Sprinkler and dual defogger in scrubbers</td>
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<tr>
<td>2014</td>
<td>Add scrubbers in wet process</td>
<td>Two-stage vertical scrubbers</td>
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<tr>
<td>2015</td>
<td>Add water-cyclone powder collector in wet process</td>
<td>Three-stage horizontal scrubbers</td>
</tr>
<tr>
<td>2016</td>
<td>Add dosing in scrubbers of facility chemical tank</td>
<td>Adding hydro-membrane in scrubbers</td>
</tr>
<tr>
<td>2017</td>
<td>Installation of high-efficient particulate filter at the terminal equipment</td>
<td>Raschig ring coating with resin</td>
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<tr>
<td>2018</td>
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Reduction in scrubber sulfuric acid concentration
Unit: mg/Nm³

- Before adding hydro-membrane: 1.680 mg/Nm³
- After adding hydro-membrane: 0.889 mg/Nm³

47% decline

Tasks of 2018

- Installation of the local scrubber at source equipment
- Installation of wet scrubber and dosing system in the facility chemical storage tank
- Effective separation of exhaust source for new process tools

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