Product Quality

Long-term Goals

- Quality Culture Enhancement
  Promote continuous improvement programs to enhance the internal quality culture
  Encourage local suppliers to participate in the Taiwan Continuous Improvement Competition to create a culture of quality and improve the competitiveness of local supply chains

- Quality Capability Improvement
  Leverage machine learning to construct an outgoing visual defect inspection and classification system for 12-inch wafers to increase employee productivity
  Develop hazardous substance analysis capabilities in chemical laboratories to ensure occupational health and safety (OHS)

- Quality Application Realization
  Based on the Company's technology roadmap, complete reliability qualification for advanced and special technologies in design and development stage

2018 Achievements

- Create an annual benefit of NT$10 billion from the enhancement programs
  ○ Target: 41,228 suggestions

- Encourage 100% local supplier participation in Taiwan Continuous Improvement Competition and 60% advancing to the finals
  ○ Target: 2025

- Increase the monthly productivity of each 12-inch wafer visual inspector to 6,125 pieces per month
  ○ Target: 2025

- Complete reliability qualification and process window characterization for the most advanced technologies
  ○ Target: 2025

- The monthly productivity of each 12-inch wafer visual inspector reached 4,928 pieces
  ○ Target: 4,860 pieces.

- Developed the ability to analyze 100% of CMR substances
  ○ Target: 2020

- Developed the ability to analyze 62% of CMR substances
  ○ Target: 49%

2019 Targets

- 43,005 suggestions from grassroots level
  ○ Target: 41,367 suggestions

- 2,196 continuous improvement cases
  ○ Target: 1,996 cases

- Attained NT$10.25 billion in combined benefits from CIT and suggestion programs
  ○ Target: 2025

- Local supplier participation reached 94%
  ○ Target: 100%

- The monthly productivity of each 12-inch wafer visual inspector to 5,250 pieces

- Developed the ability to analyze 77% of CMR substances

- Complete reliability qualification for N7+ technology and specialty technologies

- According to research and development function targets, complete reliability qualification for 5nm process technology and specialty technologies

Note: The original goal for 2020 of 100% participation is expected to be reached in 2019. Therefore, the goal was updated with the percentage of finals participation as part of the goal.
Quality is the Key to TSMC's Sustainable Operation

Semiconductors are the soul of electronic products. As the world's largest dedicated IC foundry, TSMC leads the advancement in semiconductor process technology and is committed to the improvement of wafer quality and reliability.

In order to provide customers with the highest quality products and services, TSMC has built an IATF 16949 quality management system in line with automotive industry quality standards. The Company has leveraged information technology to build a rigorous management and quality control systems for the processes of design services, technology development, mask making, wafer fabrication, and back-end services. Quality tools used in the automotive industry are applied to carry out primary product quality planning and quality control in the manufacturing stage, and the 8Ds method is used for continual improvement to ensure product quality and customer satisfaction. When changes are needed in the operation process, a cross-functional team carefully reviews the process to ensure that any changes are risk-free. Failure analyses are also conducted to find effective solutions. In addition to pursuing excellence, TSMC also promotes quality management requirements to its suppliers and subcontractors, leading partners to make continuous improvement and improve organizational health.

TSMC’s Quality Management System

- **Design Service**
  - IP / Library Development Quality Assurance
  - Design Kits Deliverables Management

- **Tech Development**
  - SPICE Model Management
  - Process Technology Development Management
  - Build In Reliability Test
  - Process Release Standard

- **Mask Making**
  - Remote Mask DB Check
  - eJobOut
  - Mask Defect Inspection

- **Wafer Manufacturing**
  - Incoming Quality Control
  - Advanced Process Control
  - EQ Real Time Monitor
  - Process Reliability Monitor
  - Wafer Acceptance Test
  - Outgoing Quality Gating

- **Backend Service**
  - Subcontractor Quality Management
  - Package Reliability Monitor
  - Outgoing Quality Gating

- **Quality Tools Application**
  - Potential Failure Mode & Effect Analysis
  - Control Plan
  - Statistical Process Control
  - Measurement System Analysis
  - Continual Improvement – 8Ds

- **Supplier / Subcontractor Quality Management**
  - Change Control Platform
  - Failure Analysis
At TSMC, quality is the responsibility of each employee and also the principle that everyone should follow when doing his or her work or providing services. In addition to improving product quality, TSMC also aspires to continue increasing customer satisfaction.

To strengthen company culture, continuously improve product quality and production efficiency, reduce production costs, and to improve customer satisfaction, TSMC promotes a grassroots-level suggestion program and Continuous Improvement Team (CIT) activities throughout the Company. Following the principle of “everyone participates”, the Company sets a target for improvement cases raised by both the suggestion and CIT programs based on employee numbers. TSMC then holds a Total Quality Excellence (TQE) & Innovation Conference, a company-wide event to present those improvement cases. The Company provides incentives, including cash bonuses and public recognition at the conference to encourage employees to strive for excellence, drive cross-team observation and learning, and enhance their innovative and problem-solving abilities. These programs greatly contribute to achieving a win-win situation of maintaining TSMC’s competitive leadership and achieving customer satisfaction. In 2018, there were 43,005 suggestions generated from the grassroots level and 2,196 from Continuous Improvement Team activities. The benefits generated from these two improvement programs reached NT$10.25 billion. Among them, 52% of the continuous improvement activities (1,143 cases) were related to product quality improvement.
Highlight Cases in the 2018 Total Quality Excellence (TQE) & Innovation Conference

<table>
<thead>
<tr>
<th>Category</th>
<th>Case</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Improvement</td>
<td>Improve the manufacturing process of wiring parts, capacitance parts, and backside capacitances parts of InFO packaging</td>
<td><strong>99.2%</strong> Reduce passive electronic components failure rates by 99.2%</td>
</tr>
<tr>
<td></td>
<td>Improve the bonding process of Hybrid Bond CIS</td>
<td><strong>91%</strong> Successfully mass produce the world’s first 1.0 micron copper-copper hybrid-bonded CMOS image sensor with a yield of 91%</td>
</tr>
<tr>
<td></td>
<td>Develop production technology for 7nm positive photosist copper bump</td>
<td><strong>83%</strong> Reduce product-specific defects by 83%, leading the technological industry</td>
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<tr>
<td></td>
<td>Apply AI, machine learning and big data technology to solve abnormal cases of statistical process control</td>
<td><strong>38.9%</strong> Reduce the number of abnormal cases in statistical process control within the processing cycle by 38.9%</td>
</tr>
<tr>
<td></td>
<td>Improve 22nm ultra-low power process technology of Random Telegraph Signal (RTS) in CMOS</td>
<td><strong>50%</strong> Reduce customer chip sizes by 50%</td>
</tr>
<tr>
<td></td>
<td>Optimize Poly Rs correction algorithm for 40nm low power process technology</td>
<td>1 Enable customer successfully launch the world’s first anti-noise Bluetooth chip</td>
</tr>
<tr>
<td>Customer Satisfaction</td>
<td>Design and develop the Frame Auto Cleaner</td>
<td><strong>14.6</strong> Save 14.6 metric tons of chemical use annually</td>
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TSMC participated in 2018 Taiwan Continuous Improvement Competition

In addition to internal cross-function-team learning and exchange, TSMC shares its experience with other industries through the Taiwan Continuous Improvement Competition. The Company hopes to drive the development of other local industries through experience sharing, and observe the improvement methods of other industries to enhance the problem-solving and innovation ability of its employees. In 2018, TSMC’s outstanding performance was awarded with four Gold Awards, one Silver Award and two Best Improvement and Innovation Awards.

In addition to strengthening the culture of quality at TSMC, the Quality and Reliability function asked local raw material suppliers to participate in the Taiwan Continuous Improvement Competition to continuously enhance performance, to promote a culture of quality and abilities among them, and to commit to a win-win situation locally. In 2018, the proportion of TSMC’s local raw material suppliers in the Taiwan Continuous Improvement Competition reached 94%, and a supplier also won its first Gold Award.

The Percentage of TSMC Suppliers participating in the Taiwan Continuous Improvement Competition

<table>
<thead>
<tr>
<th>Year</th>
<th>Actual</th>
<th>Goal</th>
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</thead>
<tbody>
<tr>
<td>2014</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>2015</td>
<td>26</td>
<td>40</td>
</tr>
<tr>
<td>2016</td>
<td>43</td>
<td>60</td>
</tr>
<tr>
<td>2017</td>
<td>74</td>
<td>80</td>
</tr>
<tr>
<td>2018</td>
<td>94</td>
<td>80</td>
</tr>
</tbody>
</table>
With the development of semiconductor technology and changes in product trends, customers keep increasing their quality requirements and expectations. The enhancement of employee's quality awareness has become crucial. In 2018, Quality and Reliability function cooperated with Fab Operation function and HR function to hold Quality Excellence training courses for the employees at fabs in Taiwan, Shanghai, and Nanjing. Through concept promotion, mindset establishment, cases study, and improvement techniques, TSMC strengthens the employee's attitude on pursuing technical excellence and exemplary quality, and carrying out the belief of 'Best Tech, Best Quality, and the Best for Customers.' In 2019, the Quality and Reliability function will regularly promote the concept of quality with cases, and add a ‘Stop & Fix’ competition group to the Total Quality Excellence (TQE) & Innovation Conference to enhance quality awareness and develop skills for employee to prevent quality abnormalities.

### Participating TSMC Cases in 2018 Taiwan Continuous Improvement Competition

<table>
<thead>
<tr>
<th>Case</th>
<th>Benefit</th>
<th>Award</th>
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<tbody>
<tr>
<td>Construct a machine maintenance automatic scheduling system, global scheduling system and an intelligent information center</td>
<td>Increased employee productivity by 49%, with a total benefit of NT$670 million</td>
<td>Gold Award</td>
</tr>
<tr>
<td>Develop 10nm wafer probe cards and automatic needle implanters</td>
<td>9 time increase in the production capacity of needle implanting</td>
<td>Gold Award</td>
</tr>
<tr>
<td>Develop Near-Infrared (NIR) sensor special structure process technology</td>
<td>3 time improvement of sensor quantum efficiency; helped customers win the annual new products award</td>
<td>Gold Award</td>
</tr>
<tr>
<td>Improve old piping and management system</td>
<td>Reduce the number of abnormal pipeline leakage to 0 per season, and reduce the cost of pipeline maintenance downtime by NT$9.4 billion</td>
<td>Gold Award</td>
</tr>
<tr>
<td>Improve AI defect image recognition systems</td>
<td>76% improvement of the Defect Wrong Label Rate, 75% shorter defect learning time, 46% defect detection time saved, with a total benefit of NT$121 million</td>
<td>Silver Award</td>
</tr>
</tbody>
</table>

With a total benefit of NT$670 million, we can see the following improvements:
- 9 time increase in the production capacity of needle implanting
- 80% reduction of the production cycle of probe head and needle implanting
- 47% reduction in the cost of each probe card, resulting in a total benefit of NT$389 million

With a total benefit of NT$389 million, we can see the following improvements:
- 3 time improvement of sensor quantum efficiency; helped customers win the annual new products award
- 76% improvement of the Defect Wrong Label Rate
- 75% shorter defect learning time
- 46% defect detection time saved, with a total benefit of NT$121 million

With a total benefit of NT$121 million, we can see the following improvements:
- Reduce the number of abnormal pipeline leakage to 0 per season, and reduce the cost of pipeline maintenance downtime by NT$9.4 billion
- 76% improvement of the Defect Wrong Label Rate
- 75% shorter defect learning time
- 46% defect detection time saved, with a total benefit of NT$121 million

Note: For details of the training course of Quality Excellence, please refer to Talent Development.
In the process of technology development, it is crucial to establish effective measurement methods to reduce variation. In 2018, the Quality and Reliability function collaborated with metrology experts in the R&D function to propose Hybrid Metrology, an analysis strategy for complex three-dimensional nanostructures. By using a variety of chemical analysis and physical measurement techniques, the demand for nano- and atomic-level feature analysis was fulfilled. Now the Hybrid Metrology analysis method has been applied towards the development of 5nm technology, and will be extended to the research and development of 3nm and specialty technologies. The analytical capabilities of 2nm Ultra-thin Film crystal structure has been completed, and the productivity of transmission electron microscopes has been enhanced by 15 percent — enough to support the research and development of 5nm and 7nm technologies.

In addition, in order to continue reducing product defects, improve process control, detect anomalies early on, and prevent quality incidents from affecting customers, the Quality and Reliability function and Fab Operation function are collaborating in a joint effort to apply advanced statistical techniques and quality tools towards the creation of an immediate defense system. By utilizing machine learning methods and the use of advanced spectral analysis, differences among processes and equipment were detected, immediately triggering improvement actions. An outgoing visual defect inspection and classification system for 12-inch wafers was established to refine the consistency of visual inspections. In 2018, the productivity of each 12-inch wafer visual inspector had increased to 4,928 per month.

The Quality and Reliability function, in collaboration with the ESH Division, has classified the current suspect materials by their risk and established a sampling plan for testing. To control and manage new materials, in addition to requiring suppliers to declare whether the provided materials contain hazardous substances, sampling tests are also carried out to ensure that their declarations are accurate. In 2018, the Quality and Reliability function further strengthened the ability of chemical laboratories to analyze suspicious substances. 62% of the substances have been analyzed for CMR effects.
Apart from meeting customer needs, pursuing customer satisfaction, and creating customer value, environmental sustainability should also be taken into consideration with product quality to ensure ecological stability and sustainable development. To conform to EU regulations and customer requirements on green products, TSMC has adopted the Hazardous Substance Process Management System IECQ QC 080000, developed by the Quality Assessment System for Electronic Components of International Electrotechnical Commission, and integrated it with the Automotive Quality Management System, IATF 16949 to establish hazardous substance management requirements in the stages of design and development, raw material procurement, supply chain management, and processing control. In 2018, through third-party auditing and certification, TSMC ensured that its hazardous substances management system and quality management system meet the requirements of IECQ QC 080000 and IATF 16949. Moreover, the products produced by TSMC are sampled and tested by a third-party external laboratory and comply with EU regulations and customers' requirements.

### Quality Application Realization

**Case Study**

First in the World — The Successful Framework Development of an Automatic Cleaning Machine

To encourage colleagues to continuously improve environmental sustainability, TSMC has added the ESH group to the Total Quality Excellence (TQE) & Innovation Conference so colleagues may explore improvement opportunities in daily business and take initiative to propose and implement countermeasures.

In 2018, the Advanced Packaging Technology and Service function improved the frame cleaning operation, which requires the use of large amounts of chemicals, and successfully developed the Frame Auto Cleaner. The cleaner not only replaces chemical substances with pure water, but also automates the entire process, effectively improving production capacity and yield rate. This improvement proposal is the first of its kind, and was awarded the TQE gold medal in 2018.

To provide excellent and reliable product quality, timely delivery for customers, ensure the safety of consumers and product applications, and prevent mass product recalls, the Quality and Reliability function helps customers to design high-quality products in the technology development and product design stage. TSMC has also implemented automotive quality improvement projects to meet the requirements of low Defect Parts Per Million (DPPM) for automotive customers.

In 2018, the Quality and Reliability function cooperated with the R&D function to complete quality and reliability qualifications of advanced logic 7nm-enhanced technology (the third-generation Fin Field-effect transistor), the third-generation application processor and InFO packaging technology of Integrated Passive Components, and the second-generation Diffractive Optical Element (DOE) of 3D sensor and facial recognition on mobile phones. Additionally, the Quality and Reliability function has worked with the Fab Operation function to further tighten process controls, wafer acceptance test, and maverick wafer handling of automotive products. With these measures, TSMC did not have any massive product recalls in 2018.

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