Operation and Maintenance (O & M) Service for Semiconductor Device Manufacturing System Which Helps Build Better Future World

Yorihiro Chiba,
Eiji Furuie,
Kazuhiko Shiraishi,
Hidekazu Takano

Keywords Lifecycle, Global environment, Energy saving

Abstract

Our Operation and Maintenance (O & M) service department specializes in providing O & M services for semiconductor device manufacturing systems, which produce key devices essential for realizing a sustainable society.

We offer comprehensive services throughout the entire lifecycle of a semiconductor manufacturing system, from initial installation and commissioning to stable operation period (O & M service period), and even equipment life extension through component repair.

Since the COVID-19 pandemic, with issues such as longer delivery time for components, there has been increased interest in used equipment and equipment life extension in the market. This leads to higher expectations from our customers to our O & M services. We are committed to providing optimal O & M solutions to meet diverse customer needs, thereby helping our clients reduce costs and improve operational efficiency.

1 Preface

Our semiconductor manufacturing system Operation and Maintenance (O & M) service division began in 1994 with operational support provided by major semiconductor equipment manufacturers. In 1996, it was established as a dedicated O & M service team for semiconductor device manufacturing systems. Through providing O & M services to customers as the contract support service for original equipment manufacturer (OEM) of the system, we have acquired technical expertise.

However, following the 2009 economic downturn caused by the Lehman Shock (the bankruptcy of Lehman Brothers) on September 15, 2008, our business performance deteriorated significantly. Taking this as an opportunity, we focused on expanding our business across the entire lifecycle of semiconductor manufacturing systems, aiming to create a business model less susceptible to economic fluctuations. Fig. 1 shows the history of our semiconductor device manufacturing system engineering services.

Starting with the technical skills acquired through contract O & M service for the OEMs, we expanded into the O & M Service for film deposition and lithography system. Simultaneously, our component repair service led to the refurbishment business of used semiconductor device manufacturing systems and the replacement business of outdated models, evolving into a system product life extension service. Recently, we have also ventured into the contract manufacturing, testing, and sales of Pure Ozone Generators (POGs), as well as the

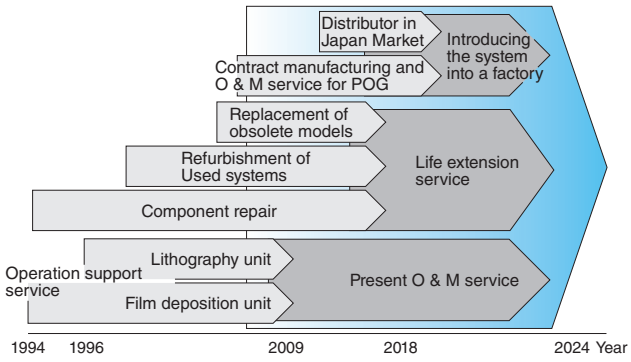

Fig. 1 History of Our Engineering Services for Semiconductor Device Manufacturing System

History and business development are shown.

equipment introduction field. Currently, we operate a wide range of businesses. This paper introduces our lifecycle engineering activities by each phase of the product lifecycle.

2 System Introduction Phase into a Factory

By providing our customers with the most suitable semiconductor device manufacturing system and the ancillary facilities, we contribute to improving the customer's productivity and enhancing their competitiveness. After introducing the system into a factory, we provide technical support, starting with maintenance training and continuing with regular inspections and troubleshooting, thus supporting our customers' efficient operation. Our main services are as follows:

2.1 POG

Fig. 2 shows the appearance of the POG. We are doing contract manufacturing service to a Meiden Group firm – Meiden Nano Process Innovations, Inc. Our service includes the assembly and testing of the POG, and we deliver and commission it at the factory of the end user. The POG stores ozone and has the capability to safely and continuously supply high-purity, high-concentration ozone gas. The use of the POG contributes to the manufacturing of advanced semiconductor devices. For example, it improves the optical system maintenance cycle (the frequency or interval at which the optical system should be inspected, cleaned, and adjusted). This optical system is a part of the lithography system (the exposure system that transfers the circuit pattern created on a computer onto a silicon wafer) used as auxiliary equipment. As of the end of March 2024, 58 POGs are in operation worldwide for this application, and this forms a part of our O & M service business.

Fig. 2 POG Unit

An image of the POG unit is shown.

2.2 Equipment Sales (Acting as a Distributor)

To fully utilize our customer bases across Japan, with whom we have established relationships through our O & M service activities, we have concluded distribution agreements with two equipment manufacturers.

One is Orc Manufacturing Co., Ltd., a leading manufacturer of optical equipment serving various industries. In 2018, we signed a distributorship agreement for Japan Market for their lithography system (PPS series) and began selling new equipment and providing O & M services to the end users. This equipment features broadband exposure using the g, h, and i lines, a variable NA function, and the ability to use a single reticle for multiple fields.

It is mainly used in organic insulating film and freewheeling diode processes for Insulated Gate Bipolar Transistors (IGBTs) of Japanese power device manufacturers and automotive analog devices.

The other company is Creden Technologies Sdn. Bhd., headquartered in Malaysia. In 2022, we entered into a distributorship agreement for Japan Market for their automated wafer handling and visual inspection microscope system (AL3300 series). This system performs macro-scale inspection of both the front and back surfaces, as well as micro-scale surface inspection, to detect and observe defects.

By handling both the sales and O & M services of these systems, we aim to expand our regular maintenance stock (investing in and cultivating the foundational assets (customers, data, know-how) to build a more robust and profitable stock business) by our efforts. In particular, we are focusing on expanding our maintenance stock for cutting-edge 300 mm semiconductor manufacturing facilities.

3 Operational Start-up and Stable Operation Phase

This section introduces the service activities corresponding to the "operational start-up" and "sta-

ble operation" phases in the lifecycle engineering of semiconductor device manufacturing systems.

3.1 "Operational Start-up" Phase

After the initial setup, we provide operation and maintenance training for customers, as well as repair services during the warranty period. Our mission is to ensure the equipment is in operation quickly and to support customers in acquiring the necessary basic knowledge and skills for operation. Clarifying roles and responsibilities between the customer and our company is essential for maintaining and improving the system's availability. For example, customers perform daily inspections and initial troubleshooting, while we handle scheduled maintenance and repairs.

3.2 "Stable Operation" Phase

We offer "on-site repair (on-call response service)" and "preventive maintenance (proactive solutions)" for POG and semiconductor device manufacturing systems. To provide comprehensive services, we also offer "on-site maintenance," where our technicians are stationed at the customer's facility to perform daily inspections, maintenance, and troubleshooting.

For "on-site repair," we maintain close communication with our customers to ensure prompt and appropriate responses based on the nature of the malfunction.

For "preventive maintenance," we propose overhauls for components at risk of deterioration and implement solutions to restore functionality. Our field service engineers strive to offer one improvement suggestion with each service visit to enhance customer satisfaction.

Due to the chronic shortage of skilled field service engineers/technicians in the industry, prompt response to unexpected failures is a challenging issue. Therefore, demand for "on-site maintenance" has increased in recent years. This service includes daily inspections, scheduled maintenance, and equipment improvement proposals based on observations. On-site presence (resident field service engineer) facilitates monitoring of the system status and allows for rapid response to malfunctions. Fig. 3 illustrates the benefits of on-site maintenance service.

In on-site maintenance service, our field service engineers support customer maintenance activities for various types of equipment. This approach promotes the development of multi-skilled field service engineers/technicians, creating benefits for both our customers and our company.

3.3 Maintenance Support for POG

Similar to semiconductor device manufacturing systems, our company handles the following

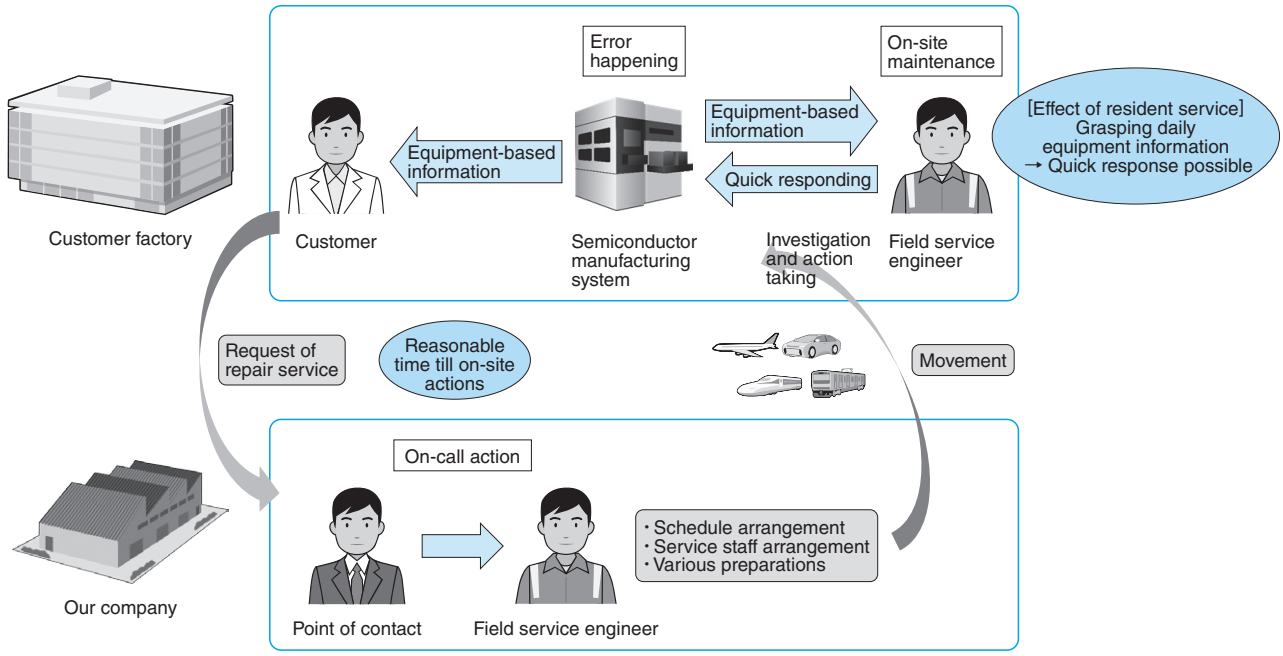

Fig. 3 **Advantages of On-site Maintenance Service**

In the "Stable Operation" phase, advantages of on-site maintenance service are shown. Recently, demand for this service has been increasing.

services: installation and subsequent maintenance and repair of POG. Since approximately 80% of our customers are overseas semiconductor factories, we require a global operation. During annual maintenance, we replace consumables such as vacuum pumps and refrigeration units, which are essential for maintaining performance. **Table 1** shows the list of parts replaced annually. To ensure safety, we also replace ozone sensors (leak detection) and ozone decomposers (detoxification). **Fig. 4** shows the process of replacing an ozone sensor.

The number of POG under our O & M service contract has been increasing annually, and further growth is expected. Since starting POG O & M service in 2014, we have consistently performed inspections and maintenance every year, completing work on 49 units in fiscal year 2023.

As mentioned earlier, since 80% of our products operate overseas, the COVID-19 pandemic that spread at the end of 2019 had a significant impact on our overseas O & M service operations. Before traveling, we spent considerable time obtaining special work visas and preparing necessary documents such as a certificate of a negative COVID-19 test result taken within 72 hours. Upon arrival, we were required to undergo quarantine at government facilities in each country (2-4 weeks), followed by quarantine at a designated facility upon returning home (2 weeks). Parts shortages persisted, leading to higher prices and longer lead times.

These issues made it difficult to obtain parts and secure field service engineers/technicians, making it impossible to maintain the scheduled inspection and maintenance cycle. To ensure safety under these circumstances, we created and provided a video instruction manual so that customers could perform ozone sensor replacement themselves. **Fig. 5** shows the text-based instruction manual and video instruction manual. This ensured the safe operation of the POG, allowing us to successfully roll over the situation of the COVID-19 pandemic without any accidents. Furthermore, the issue of procuring necessary parts was resolved by

Table 1 List of Yearly Replacement Parts

The required parts are specified to “Keep performance” and “Ensure safety during inspection” which is needed at the time of yearly POG inspection.

	Replacing parts	Replacing period
Securing safety	Ozone sensor	1 year
	Ozone decomposer	
Maintaining Performance	Vacuum pump	1 year
	Freezer cold head	
	Ozonizer filter	
	Check valve	
	Regulator	
	Pirani vacuum gauge	
	APC (Auto Pressure Control)	2 years
	Outlet filter	
	Uninterruptible Power Supply (UPS) battery	
	Adsorber	3 years
	Touch panel battery	
	Programmable Logic Controller (PLC) battery	
	UPS battery fan	4 years

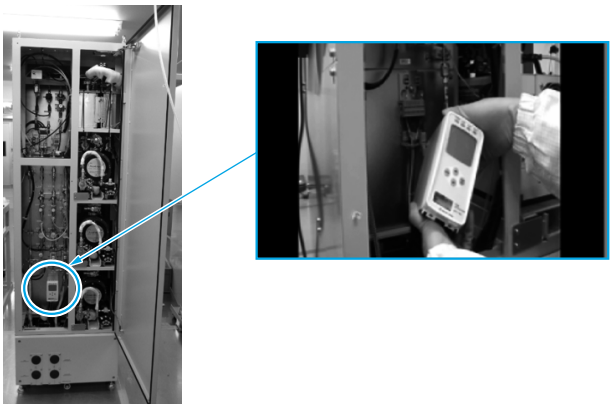

Fig. 4 View of Ozone Sensor Replacement

As shown in **Table 1**, a view of parts replacement work is shown for “Ensuring safety during inspection.”

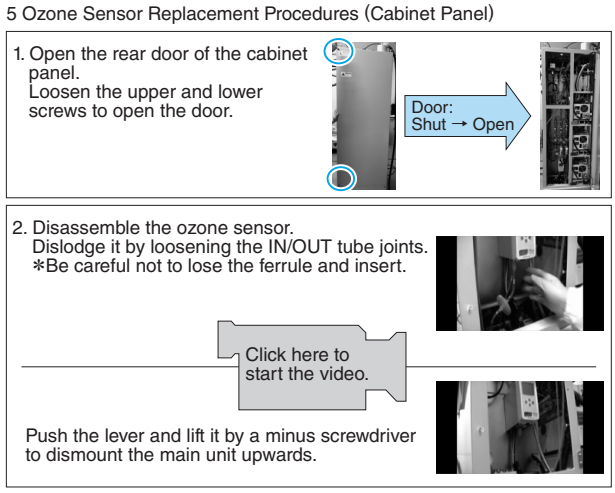

Fig. 5 Text-based Manual and Video Manual

The text-based manual with access to video manual is shown. This video was made to enable the customers to process the work by themselves.

establishing new supply channels and switching to alternative components.

4 System Product Life Extension and Renovation Phase

Semiconductor device manufacturing systems are not uncommon to be used for over 30 years. For our customers, extending the lifespan of their equipment is a top priority, and the system product life extension technologies during both the “life extension” and “renovation” phases support this.

4.1 Repair Involving Discontinued Components

Semiconductor device manufacturing system incorporates various units, and the control unit mainly consists of a Printed Circuit Board (PCB) and a DC power supply unit. The lifespan of the equipment is greatly influenced by the electronic components mounted on these units. With increasing demand for extending the life of system products that no longer receive the OEM technical support, component sourcing becomes a challenging issue, and retrofit parts are often used.

In PCB repair, sometimes the replacement parts cannot be directly mounted, requiring the creation of an adapter board. We also create additional boards with added functionality. **Fig. 6** shows a battery board for a Timekeeper IC (IC: Integrated Circuit).

The integration density of PCBs has increased year by year, and recently, surface-mount PCBs are often used, making advanced soldering technology indispensable. The transfer of these skills to the next generation is a challenging issue from now on. We are focusing on education and training to foster such transfers.

4.2 Response to Customer Requirements

In the automotive industry, the demand for power semiconductors is growing rapidly as a key technology for electrification. Recently, efforts towards carbon neutrality have intensified, and the shift from Silicon (Si) semiconductors to energy-efficient Silicon Carbide (SiC) semiconductors is progressing. Most of the equipment currently used in power semiconductor manufacturing is over 20 years old and designed to process Si wafers. Therefore, modifications to the transport system are necessary to accommodate translucent, light-transmitting SiC wafers. However, since manufacturer support often ends, adapting to SiC wafers is often not feasible.

To meet these demands, we have been working on SiC wafer compatibility for over 10 years, and we still receive many inquiries. While infrared and visible light are commonly used as light sources for wafer detection, they cannot be used for SiC wafers because they penetrate through the material, preventing accurate detection. To address this, we developed and implemented a solution using ultraviolet (UV) light, which does not penetrate SiC. This allowed us to achieve SiC wafer compatibility without significantly altering the wafer detection mechanism of the equipment. **Fig. 7** shows an image of SiC wafer detection using UV light.

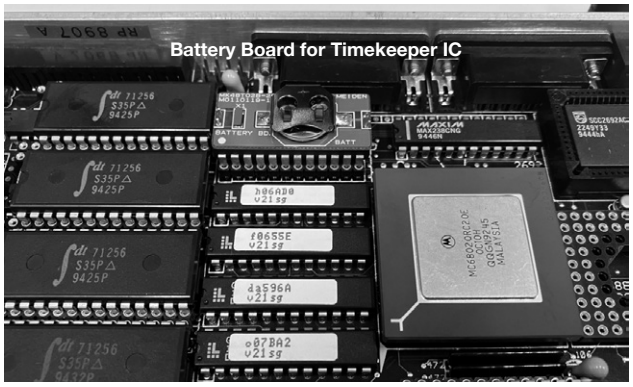

Fig. 6 Battery Board for Timekeeper ICs

As an example of our life extension service, we developed a custom circuit board to address the issue. This involved designing and adding a battery board to extend the life of the IC chip that uses a battery.

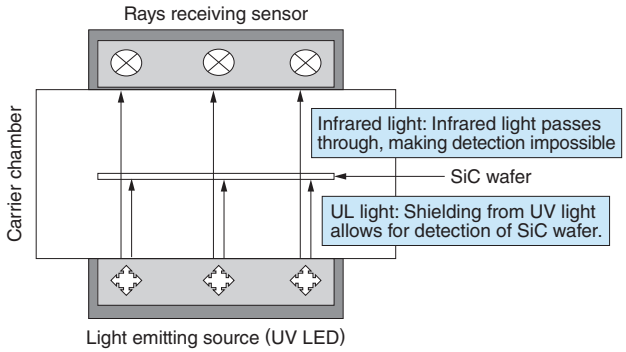

Fig. 7 Image of SiC Wafer Detection Using Ultraviolet Ray

This section presents an example of how we developed and implemented new technology to address customer requests for extending the life of older equipment.

4.3 Replacement of Older Units

General-purpose logic devices and automotive-grade devices do not require high-performance, cutting-edge manufacturing equipment. Manufacturing lines often rely on equipment installed in the 1990s, and the shortage of spare parts for these older systems is a major issue.

For equipment manufacturers, developing entirely new, functionally equivalent products is not practical due to the difficulty in recouping investment costs. However, by reproducing equipment based on the original design, even with discontinued components, it is possible to recreate the equipment with high technical expertise and a robust supply chain. For example, for ICs used in PCBs, we search Japanese and international markets for reliable sources of stock, and if necessary, select suitable alternatives based on specifications and dimensions, implementing special procurement and quality control measures.

Examples of our work include reproducing controller units based on the original component configuration and replacing older operation monitors with modern color touch panels through interface upgrades. These efforts support the system product life extension as the time calls for such system product life extension badly.

4.4 Equipment Refurbishment

To contribute to a sustainable society, we reduce waste and promote reuse through our equipment refurbishment service, thus minimizing environmental impact.

This service refurbishes the older systems to meet customer specifications. We procure the used systems from Japanese and international markets, perform overhaul, modifications, and component replacement, and conduct various inspections before supplying approximately 160 units to date. The recycling equipment offers significant advantages to customers in terms of price and delivery time, and allows for improvements in manufacturing processes and productivity.

5 Postscript

Semiconductors have become indispensable to modern society. For the realization of a sustainable society, lifecycle engineering of semiconductor manufacturing equipment, which supports 24/7 operation, is essential.

Going forward, we will continue to address the increasingly diverse needs of our customers and contribute to society by providing reliable technical support services, always striving to be a reliable and supportive service provider for our customers.