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MAINTENANCE AND MANAGEMENT OF LASER DIRECT WRITING LITHOGRAPHY MACHINE

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Abstract: The laser direct writing lithography machine is a key equipment for integrated circuits and semiconductor manufacturing. And it is a complex and highly precise device consisting of an optical system, mechanical system, electronic system, and computer system. The maintenance and management of the lithography machine directly affect the quality and stability of the lithography products, and ultimately influence the work efficiency of users and the competitiveness of enterprises. In response to the above issues, this paper proposes management and maintenance measures for laser direct writing lithography machines and related equipment, which is helpful to improve the usage and maintenance capabilities of users and manufacturers, reduce equipment operation costs, and provide useful references for the maintenance and management of precision equipment.
Keywords: Laser direct writing; Lithography machine; Machine maintenance; Management measure

1 INTRODUCTION

As a high-precision and highly versatile machine, the laser direct writing lithography machine designed for fields such as MEMS, microelectronics, optics, sensors, material sciences, quantum device. Because the exposure data of the laser direct writing lithography machine is directly obtained from the graphic design data, and it replaces the traditional mask-based exposure with maskless exposure, this results in a more complex optical system. The performance of the lithography machine directly affects the quality and stability of the products. Moreover, due to the complex structure of the lithography machine and the high difficulty in maintenance, most of the maintenance work for these machines relies on the services provided by the equipment suppliers. When the supplier stops providing maintenance services, it will seriously affect the status of the lithography machine and the quality and reliability of related products[1-3].

2 THE BASIC STRUCTURE OF THE LITHOGRAPHY MACHINE

The exposure principle of the laser direct writing lithography machine is that a laser beam with controllable area and intensity performs the exposure operation on the photoresist on the substrate surface. The laser direct writing lithography machine is mainly composed of an optical system, a movable stage system, an electronic control system, a computer system, a box system, and the auxiliary power supply, water supply, and gas pressure supply accessories for the lithography machine[4-6].

2.1 Optical System

The optical system is composed of multiple modules, and its main functions include the emission and stabilization of laser beams, control of focal length, as well as monitoring of the camera system. The optical system generally includes laser heads, beam expanding modules, stabilization modules, pixel control components (such as Digital Micromirror Devices, Programmable Diffraction Gratings, etc.), Zoom modules, stitching control components, write head components, camera modules, etc. Some dual-path optical systems also include path matching components.

2.2 Stage System

The movable stage system is usually installed on a fixed granite surface. The combination of the granite and the air buffer system can effectively isolate vibrations, and its low thermal expansion coefficient feature can maintain the stability of the system structure. The platform system generally consists of rail-type or air-floating platforms, control systems, vacuum systems, and interferometers. And precise stage control is the key to ensuring the stability and accuracy of the exposure position[7-9].

2.3 Electronic Control System

The electronic control system is composed of multiple components, generally including the system control rack, motor control rack, exposure pixel control rack, and some other signal control and compensation racks. The system control rack contains all the control units used for data processing and positioning. The motor control rack includes optical device motors and loading machine motors, etc., and the exposure pixel rack includes all the data flows flowing to the exposure pixel control components.

2.4 Computer System

The user computer serves as the control bridge between the user and the lithography machine. Operators rely on the control computer to execute operation instructions when performing production tasks on the lithography machine, and maintenance engineers also need to do so when conducting maintenance operations. The conversion computer converts various formats of design files into machine-readable pixel datasets, ensuring the control of the lithography machine over the exposure images.

2.5 Box System

The box system is designed to provide a stable environment for the lithography machine in terms of temperature, humidity and air flow, ensuring constant exposure conditions, thereby minimizing the variation in exposure performance. The box usually also has a hatch, observation window, control buttons, and some even have a loading mechanism.

2.6 Auxiliary Components

The operation of the lithography machine also requires auxiliary components that provide air pressure, cooling circulating water, and stable electrical power. These components include vacuum pumps, filters, ice water machines, power supplies, etc. Their water pipes, air pipes, and wires are directly connected to the interior of the lithography machine.

3 MAINTENANCE AND MANAGEMENT OF LITHOGRAPHY MACHINE

The maintenance and management measures for laser direct writing lithography machines should include state monitoring, general maintenance, and troubleshooting, etc.[10-11]

3.1 State Monitoring

The status monitoring of the laser direct writing lithography machine is an important step to ensure the stable operation of the laser direct writing lithography machine. It usually includes granite level check, platform movement test, platform wiring, water pipe, and air pipe inspection, system vacuum pressure check, monitoring of the internal and external environmental temperature of the lithography machine and the temperature of key components of the optical system, monitoring of the water circulation system flow and temperature, monitoring of laser energy and running time, monitoring of beam stability, and inspection of interference signal. For the mechanical structural components in the lithography machine system, regular checks, cleaning, lubrication and other operations need to be carried out to ensure the good condition of the mechanical structure and avoid serious equipment failures caused by mechanical faults.

3.2 General Maintenance

The general maintenance measures for a laser direct writing lithography machine include restarting the computer system, intensity correction, exposure testing, etc.

3.2.1 Restarting the computer system

The lithography machine performs regular restarts of the computer system. Over time, a system that operates continuously is prone to issues such as cache accumulation and system slowdown. Regularly restarting the system can free up memory cache, optimize system performance, and ensure the efficient operation of the lithography machine's control and conversion systems.

3.2.2 Intensity correction

The energy intensity distribution of the exposure pixels of the lithography machine directly affects the systematic brightness changes within the exposure line. If not corrected, this distribution can cause size deviations in the stripe structure or its boundary positions. Usually, the automatic intensity correction program in the lithography machine software is used to set and change appropriate correction parameters to complete the energy correction. Energy correction is a key step to ensure the exposure quality, and the correction curve is also an important tool for monitoring the state of the optical system.

3.2.3 Exposure testing

An important means to determine the status of the laser direct writing lithography machine is to judge the current status of the lithography machine based on the exposure results of the test graphics. Some of the structures in the exposure test graphics, as shown in Figure 1.

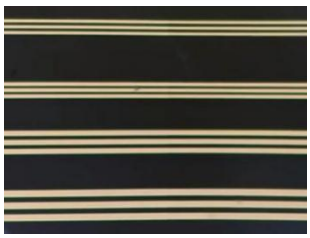

Figure 1 Different Thicknesses of Linear Arrays in Test Graphics

Test graphics generally include horizontal and vertical lines of different widths, diagonal lines of different angles and directions, circular, rectangular, triangular structures and line array, square matrices, etc. These are all important indicators for judging the current performance and parameters of the lithography machine.

3.3 Troubleshooting

Common faults of laser direct writing lithography machines include mechanical failures, electronic failures, computer system failures, and optical system failures, etc.

3.3.1 Mechanical failures

Common mechanical failures include wear of mechanical components such as leakage in intake and exhaust pipes, leakage in cooling water pipes, wear of guide rails, failure of cylinders, and exceeding of motor stroke limits, etc. The general measures for handling faults include locating the source of the fault, inspecting the damage, replacing the damaged parts, and conducting inspection and testing, etc. It should be noted that when performing maintenance tasks on the water circulation system, the water circulation booster device should be turned off, and water should be prevented from splashing onto electronic components and optical components.

3.3.2 Electronic failures

Common electronic faults include power line faults, sensor faults, communication system faults, and control system failures, etc. Modern lithography machine systems are equipped with a fault reporting system. When a certain system fails, it will notify the operator and maintenance engineers. The engineers can perform fault detection and elimination work for the specific system based on the fault information. Generally, a multimeter and an oscilloscope are used to measure the voltage and signals at the fault source. The troubleshooting measures taken include resetting the faulty system and replacing electronic components, etc.

3.3.3 Computer system failures

Common computer system failures include software vulnerabilities, insufficient memory, damaged system files, and system crashes. Engineers usually need to take measures such as upgrading software, optimizing code, restarting the system, and replacing the host to troubleshoot the faults based on the situation of the software system failure. It should be noted that during the maintenance of the software system, it is necessary to back up the system and file materials in advance to ensure that the system can be restored to its original state.

3.3.4 Optical system failures

The optical system is the most complex and precise core component of the lithography machine. Common optical system failures include significant deterioration in exposure quality, failure to adjust exposure parameters, etc. The uneven distribution of exposure energy is shown in Figure 2.

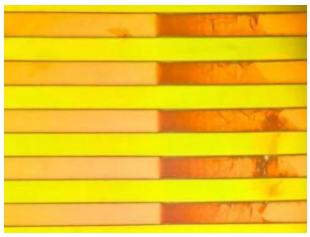

Figure 2 The Uneven Distribution of Exposure Energy

Generally, measures such as checking the light spot state, checking the optical axis position, checking the laser energy, and checking the beam stability will be taken to determine the source of the failure. The failure sources include optical lenses, pixel control components, heads, etc. After replacing the faulty components, it is usually necessary to perform optical path adjustment work. The optical path adjustment is very complex and requires combining each adjustment status with exposure testing to ultimately restore the exposure performance of the lithography machine system. The optical system maintenance service of the lithography machine is generally provided by the equipment manufacturer.

4 MANAGEMENT STRATEGIES AND METHODS

The management strategies and methods for laser direct writing lithography machines should include establishing a comprehensive maintenance plan, formulate emergency response plans and troubleshooting checklists, signing maintenance contracts with equipment manufacturers, and enhancing the ability of independent maintenance[12-13].

4.1 Establishing A Comprehensive Maintenance Plan

The laser direct writing lithography machine requires the formulation of maintenance plans of different depths. Generally, experienced equipment engineers are responsible for the daily, monthly and quarterly maintenance tasks. Daily maintenance should include monitoring the status of the lithography machine such as air pressure, temperature and humidity. Weekly plans include tasks such as restarting the system, energy calibration and exposure testing of the lithography machine. Quarterly plans should include tasks such as checking the Granite level, lubricating the mechanical structure and detecting signal strength. When encountering difficult faults, it is necessary to contact the equipment supplier promptly to seek technical support. A complete management plan for the lithography machine is the basic condition for ensuring the stable operation of the lithography machine.

4.2 Formulate Emergency Response Plans and Troubleshooting Checklists

The laser direct writing lithography machine has a complex structure system, which makes it prone to various failure phenomena in different systems. In particular, emergency plans should be established for faults in the power supply and water circulation systems to enable operators to promptly cut off the fault source and prevent the expansion of the failure. At the same time, the failures of the laser direct writing lithography machine are not all obvious. Its failures also include the deterioration of exposure quality due to abnormalities in the optical system or the platform motion system. These failures need to be judged through actual exposure tests and the exposure results of the finished products, and a long-term and effective fault elimination list should be established to help quickly solve the same type of failures, grasp the patterns of failure occurrence, and quickly restore the original performance of the lithography machine.

4.3 Signing Maintenance Contracts with Equipment Manufacturer

For many technical issues and troubleshooting tasks of the laser direct writing lithography machine, only solutions provided by professional and experienced supplier engineers can be effective. Moreover, many key components of the lithography machine can only be purchased from the equipment manufacturer. Without professional training and lacking experience, operators who attempt to manage and maintain the lithography machine on their own are highly likely to cause irreversible faults in the machine. Therefore, signing a long-term service contract with the supplier for the maintenance of the lithography machine is the best solution to ensure the stable operation of the machine.

4.4 Enhancing the Ability of Independent Maintenance.

The maintenance work of laser direct writing lithography machines is often highly dependent on the equipment supply vendors. In case the equipment vendors stop providing services, it is likely to cause the deterioration of the equipment's operating condition or even its complete shutdown. Therefore, enhancing the self-maintenance capabilities of lithography machine users can effectively ensure the long-term stable operation of the equipment. Measures to improve the self-maintenance capabilities include inviting equipment vendors to provide regular training, stocking spare parts for key components, and establishing user maintenance experience forums, etc.

5 CONCLUSION

The maintenance and management of laser direct writing lithography machines are more complex than those of ordinary precision instruments. The maintenance work involves multiple aspects such as mechanical systems, electronic systems, optical systems, and software systems. Each system has high precision and complexity, so the maintenance and guarantee capabilities of the lithography machine are more demanding. Establishing effective maintenance and management strategies and emphasizing the cultivation of highly skilled maintenance personnel are effective measures to ensure the normal operation of the lithography machine. At the same time, the performance of laser direct writing lithography machines is related to the maintenance capabilities of users. Only professional, efficient, and precise maintenance and management methods can maximize the optimal performance of the lithography machine and ultimately improve the quality and stability of enterprise products[14-15].

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

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