Drain Diverter

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ABSTRACT

Drain Diverter

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The DI water is commonly used to rinse production wafers to remove mechanical and chemical residue without any problematic chemical reaction in rinse process. The semiconductor industry wants to save their manufacture cost and reduce the industrial residue by recycling the deionized water during CPM process. The conductivity in recycled DI water is integrated over the time period.

The Drain Diverter, deionized wafer filtering system, is the automated system that detects the level of ions and controls the drain system by using conductive probes. The system contains hysteresis loop, valve feedback, relay circuit, and facility interlock. The recycled water valve is immediately closed when the contaminated water is detected by the conductive probes.

The Drain diverter is the project designed for the semiconductor equipments company, and is currently integrated and operating in semiconductor manufacture facility of a chip maker, filtering contaminated DI water from the chamber. And the time delay of the recycled water valve responses is 140mSec for 60PSI of flow pressure.

ACKNOWLEDGMENTS

The content of this report is industrial confidential. Thus, all figures are omitted from the report.

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I. Introduction

Chemical-mechanical planarization or Chemical-mechanical polishing, commonly abbreviated CMP is a technique used in semiconductor fabrication for planarizing a semiconductor wafer or other substrate. The process uses abrasive and corrosive chemical slurry (commonly a colloid) in conjunction with a polishing pad and retaining ring, typically of a greater diameter than the wafer, making the wafer flat or planar.

In order to complete the CMP process, one of its step requires cleaning up all chemical and mechanical residues by draining deionized water. The deionized water could be recycled and reused until the level of ions in is greater than certain threshold for a cost saving and an industrial waste reduction. The Drain Diverter is the system that detects the level of ions using conductive probe, and controls drain valves for new and reclaimed deionized water.

Figure 1 Water valve diagram is omitted

As it is shown on figure 1, two conductivity sensors are placed on the water valve assembly to measure the level of ions. The water valve assembly is specially designed so that the sensors are under water all the time in order to insure the reliability of the sensor.

The new DI water valve is normally opened, and the recycled DI water valve is opened if and the only if the level of ions on the water is lower than the threshold agreed by the both sensors.

II. Requirements

- Electrical conductivity threshold = threshold
- Methods of logic evaluate the threshold;
 - Analog (transistor level PCB design) system
 - Digital (PLC based) system
- Logic fails if new and recycled deionized water are drained together
- Alarms the interlock and stop recycled DI water if the logic fails
- Number of channels = 5

III. Design

A. System mechanical overview

Figure 2 System mechanical overview is omitted

The system contains electrical and mechanical components. The analog controlled circuit and PLC are electrical portions. The output of every electrical circuit design has to be evaluated by two methods. The one is the analog circuit which is run by transistor leveled, and another method is the digital circuit which is run by PLC typed. The levels of ions in the water are calculated using analog circuit and digital circuit. And the results have to be agreed with each other in order to drain recycled Di water.

PLC is programmed and controlled by display panel view, and it is powered by the 25V and 5A power supply. The level of ions can be monitored from display panel view.

Analog & digital channels are also part of PLC that receives analog and digital input signals from analog controlled circuit. Analog input signal is the level of the ions received

from the conductivity sensor to analog controlled circuit, and the digital input signal is the calculated output voltage from the hysteresis loop.

The mechanical components are solenoid manifold and drain diverter, and they are controlled by the electrical systems. The solenoid manifold is the system gives either open or close commands to pneumatic valve, and controlled by analog circuit. Drain diverter gives either opens or closes command to the water valves which are pneumatic convey system.

The system is designed to have either recycled DI water or new DI water provides to the chamber. And there are several logic circuits installed that check circuit logics to prevent any production water contaminated from the high level of ions of recycled water in case any electrical components fail. More details are covered on chapter E. Water valve feedback circuit, and chapter F. Relay circuit. If the logic fails, the alarm will sound, and stop feeding recycled water into the chamber at same time.

In case of emergency for any reasons, the operation of the system can be stopped by hitting the emergency off switch; EMO. It is the safety feature.

B. Conductivity sensor

Figure 3 Conductor probe configure [George Fischer Signet 2009] is omitted

The conversion factor is set to be 4 - 20mA = 0 to $10 \times 10^{-6} \text{ S} \cdot \text{m}^{-1}$ since the customer requirement is to drain recycled back to the chamber if the electrical conductivity is lesser than threshold. George Fischer Signet, Inc guarantees the accuracy $\pm 2\%$ of full scale with the resolution of $7\mu\text{A}$. The maximum update delay is 600ms for the operating temperature of -10°C to 85°C .

Figure 4 Conductor probe test set is omitted

The spec of the probe is confirmed before integrated into the system by directly measuring the output current loading on the 250Ω from the deionized water.

C. Drain diverter assembly

Figure 5 Drain diverter assembly is omitted

The level of ions is measured by conductivity probe (CP01 & CP02). Each probe is located after wafer control valve for double protection. The recycled water is reused if the level of threshold is satisfied by both probes. The recycled DI water valve (PV02) and the new DI water valve (PV01) are controlled by the system. And it sends feedback signal back to the system whether open or closed. In order to pass the logic, it has to be either the recycled DI water valve (PV02) closed and the new DI water valve (PV01)

opened, or the recycled DI water valve (PV02) opened and the new DI water valve (PV01) closed. Otherwise the system alarms the interlock, and stops the operational process. There total five Drain Diverter Assembly systems exist on single PCB that controls five different chambers.

D. Non-inverting Hysteresis Loop

Figure 6 Hysteresis Loop Block is omitted

The current loop from conductivity probe bypasses PLC and feeds into Current Loop Receiver, and converted from 4mA ~ 20mA to 0V ~ 5V voltage. Then converted voltage feeds into the voltage comparator. The threshold is equivalent to current converted from the conductivity probes. And the current is converted to voltage through Current Loop Receiver.

Figure 7 Hysteresis Loop is omitted

The hysteresis circuit sets voltage threshold high as TH and threshold low as TL [Moghimi 2000]. Those values are $\pm 2\%$ of overall range of the conductivity sensor and are comparable to threshold. The hysteresis range is determined by the accuracy of the sensor which is $\pm 2\%$ of full scale. As it shown on Figure 7, recycled DI water valve will be closed when the conductivity is reached to TH, and opened when it is reduced to TL. The reference voltage is set by a voltage divider. The threshold voltage is calculated to be satisfied with the electrical conductivity is lesser than threshold. When the input voltage is lesser than the threshold, the BJT (bipolar junction transistor) located at the output stage in the amplifier is electrically shorted between collector and base junction [Franco 1998]. Then the voltage across “R emit” shorts the junction between collector and base on the BJT in Relay Block. Thus, the relay 15 is energized.

As an example, let's assume the level of ion in the recycled water is low. Then the conductivity should be low as well as the low current flows into the current loop receiver.

Then it will close the transistor in the comparator location on the output stage. In results, the voltage across on R emit is high then the relay on the relay block will be energized. The current loop from conductivity probe also travels through 250 ohm PLC input module. And the level of voltage is also calculated using digital system to find the electrical conductivity given. Then, PLC calculated the electrical conductivity of DI water has to be agreed with voltage comparator results using hysteresis circuit in order to reuse the recycled DI water, namely AND logic [Gopalan 1996].

E. Water Valve Feedback Circuit

Figure 8 Valve Feedback is omitted

The purpose of the Water Valve Feedback Circuit is to evaluate the functionality of the valves. The wafer valve is controlled by the logic circuit, and it provides the feedback signal either Open or Close. In order relay K17 to be energized, the system needs to receive either 'IWN OPEN (New DI water controlling valve) and RECLAIM CLOSED (Recycled DI water controlling valve)', or 'IWN CLOSE and RECLAIM OPEN'. It means the system verifies that the recycled DI water and new DI water are not flow into the chamber at same time, and either the recycled DI water or new DI water are flows into the chamber all the time.

As an example, if the recycled water contains ions below the threshold, relay28 is energized, and the current flows from PLATEN 2 IWN CLOED. Thus, relay17 will be energized because the ground of relay17 is provided by two cascaded transistor. The reason of two transistors instead of single is safety. In case of one transistor fails, it could be either permanent short or permanent open. If it is permanent short, the system will drain the recycled DI water with infinite loop, and will contaminate the process wafers. The possibility of the transistor failure is low. However, by adding one more transistor serial, the chance of the permanent open becomes half. So it will help to protect the process wafers which are costly.

F. Relay circuit

Figure 9 Relay Circuit is omitted

EV5 is the switch for the water valves; IWN valve and Reclaim valve. IWN valve is normally opened, and is closed when EV 5 is energized. Reclaim valve is normally closed, and is opened when EV 5 is energized. It means that EV 5 is being energized if the system wants to reuse the recycled water. In order EV 5 to be energized, three conditions have to be met. First, Relay 17 is closed by verifying the functionality of the valves from the Water Valve Feedback Circuit. Secondly, Relay 15A is closed which means the level of the ion in the recycled water is lower than the threshold confirmed by the Noninverting Hysteresis Loop. And for the last, Relay 16A is closed. Relay 16 is controlled by the PLC module. Relay 16A is closed if the calculated value of the electrical conductivity using digital system is verified to be clean.

As an example, let's assume the recycled water contains ions below the threshold. Relay 17 should be closed as long as the recycled water valve and new DI water valve are not

opened or closed at same time. And relay15 should be closed as a result of the hysteresis loop. And relay16 should be closed too if PLC agrees the results of calculation with the hysteresis loop. Then finally, EV5 will be energized to open the valve for the recycled water valve.

Relay 20 is a part of the Facility Interlock system, and should be energized all the time for the following two conditions. First, the level of ions in the recycled water is higher than the threshold. Then, Relay 29B is closed by Water Valve Feedback Circuit. Secondly, the level of ions in the recycled water is lower than the threshold. Then, Relay 15B is closed by the Noninverting Hysteresis Loop. Relay 17 is closed for both cases by Water Valve Feedback Circuit.

G. Facility Interlock

Figure 10 Facility Interlock is omitted

Relay 21A secures the Facility Interlock. Drain Diverter controls the drain clean system of total five different chambers. Relay 20B confirms the logic of the drain system of one chamber, and the other four relays confirm the rest of them. Thus, Relay 20A is energized if there is no abnormality found from five chambers in terms of the system logic and facility conditions.

Let's assume the recycled water is dirty, and the recycled valve is somehow opened at same time. Then relay20 from Figure8 should not be signaled. In results, relay21 in Figure9 will not be energized. And it makes FACILITY block to be opened.

IV. Test results

Figure 11 Test setup is omitted

The test setup has been made to confirm the functionality of the system. The purpose of the test has two objects. The first one is to check the basic performance of the relay circuit and feedback system. Initially, the pure DI water flows through the reclaim valve. Moment later, drop contaminated water in. And what we want to see is that the recycled valve closes at same time. The second object is to measures the signal across the two relays; relay15 on channel 1 and relay 29 for channel 2, by using the oscilloscope. And measure the actual feedback and time delay from those relays. The reading on relay 15 should be high if the level of ion in the recycled water is low. As well as the reading on relay 29 should be high is the recycled valve is closed.

Figure 12 Recycled water valve response – 60PSI is omitted

The functionality of the system is verified by measuring the response of the relays. The deionized water feeding onto the drain system by conductivity probes are changed to the contaminated water. Then, the voltage is measured across the relay locating on the output stage of the voltage comparator, and the relay energized by the feedback signal of the recycled water closed valve. As soon as non-deionized flows into the system, the hysteresis loop circuit picks it up. In results, the recycled water valve is closed. The response time for the process takes 140ms with 60PSI of water pump pressure. If it gives long delay, then more contaminated DI water will be drained into the chamber. However, 140ms is fairly fast enough.

When the current flowing through the relay stops immediately, it will provide reverse polarity and will theoretically apply the infinite reverse current. Of course, it will be

compensated by the kick back diode. However, it may give effect on ground, namely transient ground loop. The peak observed on Figure 11 could be explained from it.

Figure 13 Recycled water valve response – 90PSI is omitted

As the speed of water flow gets faster by changing the pressure of the water pump to 90PSI, the response time also reduced to 68ms. This is expected because the water valve is originally opened against the source of the water, and the valve is closing to the same direction of the flow when the level of the ions increased over the threshold. Thus, the higher pressure of water flow helps the water valve to be closed.

V. Conclusions and Recommendations

The drain diver converter is requested by the customer to save the production cost and to reduce the industrial waste by recycling the deionized water, and installed on customer's production chamber while running. The sensitivity of the system depends on the hysteresis circuit which decides the level of ions in the recycled water. The level of ions is determined by contamination of the surface of the water calculated by the number of particles.

The output of every electrical circuit design has to be evaluated by two methods. And the one is the analog circuit which is run by transistor leveled, and another method is the digital circuit which is run by PLC typed. The levels of ions in the water are calculated using analog circuit and digital circuit. It is the internal regulation of the system policy. The results of the analog and digital output are linked to the input stages of the AND gate, and has to be agreed each other. And my project is the portion of the analog circuit design. If the response time gives significantly longer delay, it may open relay 20 because relay 29B acts long after relay 15B is opened. The RC delay circuit may need to be cascaded with relay k29 to compensate the maximum response delay and stabilize the system logic as a future reference.

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