

The Detection of Empty Resist Bottles or Air in the Resist Lines of a Photolithography Coating Tool

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Abstract

Photolithography is when light is used to put an image from a photo mask onto a wafer that has photo resist on it thus creating integrated circuits or other technology such as read/write heads for hard drives. Reservoir Switching Units can fail to detect resist on the Photolithography tool or the Millipore pump thus introducing air into the resist lines and ultimately causing scrap due to poor dispenses on under layer processes. This is difficult to detect via operator inspection. It is important to improve the dispense system on a Photolithography coating tool because with the increasing cost of photoresist there is a need for less waste. There are more read/write heads on a wafer and larger wafers therefore if the Photolithography coating tool has a poor dispense which is not detected and a wafer is scrapped, this will increase manufacturing costs. By reducing the amount of scrap and rework, there will be a reduction in the time to produce a single wafer thus reducing the overall production costs of making a single read/write head therefore staying more competitive in the hard drive market. This paper outlines a method for detecting empty resist bottles or air in the resist lines using Programmable Logic Controller technology in conjunction with a relay dispense system to monitor the dispense system from a remote station,

thereby improving the process and reducing cost of manufacturing read/write heads. Overall, there are less dispense errors, thus less rework and scrap, yield on the wafer had improved and therefore has reduced the cost of manufacturing a read/write head and also the time to market has improved. Due to the success of the PLC control system the system will be implanted across other coating tools in the factory.

Keywords: Photolithography, Programmable Logic Controllers, PLC control, process control,

1. Introduction

In today's world of semiconductor manufacturing customers must be supplied with the right technologies and solutions at the right time. To achieve this, the semiconductor industry must become more efficient, reduce production time for each wafer, reduce waste and also be able to adjust production to match customer demands. The photolithography process is used in the production of hard drives in the semiconductor manufacturing and the equipment that is used in the dispense system

Lithography is one of the process's that has advanced in a few decades in the drive to make smaller read/write recording heads for the disc drive market. The process of photolithography consists of a wafer being coated with a light sensitive polymer called photoresist is put on the wafer, then a pattern is exposed on the wafer and developed to form a three-dimensional image on the wafer as seen in Figure 1. As the cost of equipment has remained constant the cost of materials such as photoresist had drastically increased and also as designs have become more complex there is need for multiple layers thus using high volumes of chemicals (Couteau et al., 2011). As photolithography costs account for about 30% of the manufacturing of a wafer in the semi-conductor industry (Mark, 2012), therefore by improving the coating process

there can be a reduction in the amount of resist being used and therefore a reduction in the costs of manufacturing a wafer.

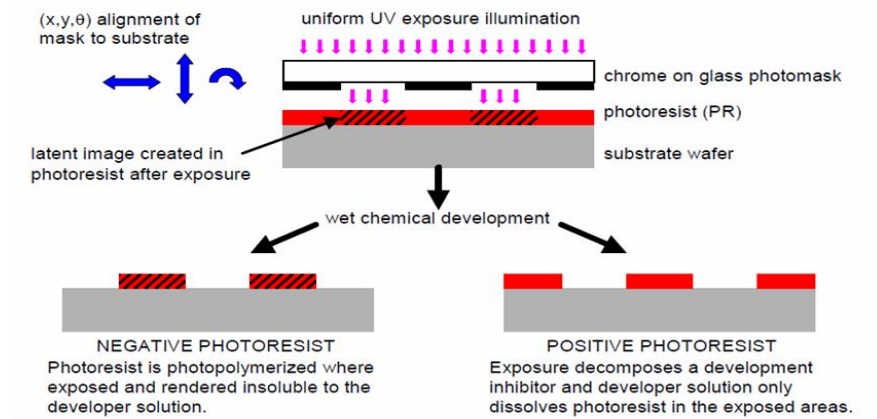


Figure 1: Photolithography process

Photolithography is a micro fabrication process to pattern parts of a thin film or the bulk of a substrate (Jaeger, 2002) by using light to send a geometric pattern from a photomask to a light-sensitive chemical "photoresist" on the substrate. An engraving of the exposure pattern into the material underneath the photo resist takes place through a series of chemical treatments. It does share some similarity with photography in the exposure of the pattern although later stages in the process have more in common with etching than with lithographic printing. A disadvantage is that it needs a flat substrate to start with and is not very effective at creating non-flat shapes. It also needs extremely clean operating conditions hence the modern day clean rooms used (Pease and Chou, 2008). Photolithography continuously improves with newer techniques using excimer laser lithography printing features with dimensions a fraction of the wavelength of light. Alternatives to conventional UV are outlined here.

Extreme ultraviolet lithography uses an extreme ultraviolet (EUV) wavelength (Harilal et al., 2006) and is a large departure from the deep ultraviolet lithography technique. EUV lithography takes place in a vacuum because all matter absorbs EUV radiation

and all optical elements need to make use of defect-free Mo/Si multilayers which reflect light by means of interlayer interference.

Nanoimprint lithography fabricates nanometer scale patterns with low cost, high throughput and high resolution (Kumar et al., 2009) through creating patterns by mechanical deformation of imprint resist and subsequent processes. Nanoimprint lithography has been used to fabricate devices for electrical, optical, photonic and biological applications. An advantage is its simplicity and the largest cost associated with chip fabrication is the optical lithography tool used to print the circuit patterns.

Electron-beam lithography scans a focused beam of electrons to draw custom shapes on a surface covered with an electron sensitive film called a resist (Parker et al., 2000) so that the beam changes the solubility of the resist enabling selective removal of regions of the resist by immersing it in a solvent. This creates small structures in the resist that can be transferred to the substrate material, typically by etching. This allows the drawing of custom patterns with sub-10 nm resolution but is restricted to photomask fabrication and low-volume production of semiconductor devices.

X-ray lithography uses X-rays to place a geometric pattern from a mask to a light-sensitive chemical photoresist on the substrate where chemical treatments then engrave the produced pattern into the material beneath the photoresist (Vladimirsky et al., 1999). Due to their short wavelengths (<1 nm), X-rays overcome the diffraction limits of optical lithography, allowing smaller feature sizes.

Ion beam lithography scans a focused beam of ions in a patterned fashion across a surface in order to create very small structures such as integrated circuits or other nanostructures (Parikh et al., 2008). It was discovered to be useful for transferring high-fidelity patterns on three-dimensional surfaces. Due to Ion beam lithography allowing higher resolution patterning than UV, X-ray, or e-beam lithography due to the heavier particles possessing more momentum, it allows the ion beam to have a smaller wavelength than even an e-beam and therefore almost no diffraction.

The Polaris Track¹ is a multi-process chamber tool used to coat wafers with photo-resist, and develop exposed wafers as can be seen in Figure 2. In addition to the coating and developing stations, the tool contains numerous wafer bake and chill stations for heating and cooling of the wafers. Wafers are automatically moved between process chambers by a number of wafer handling systems, one of which is either one or two centrally located robots. Smaller dedicated wafer handlers are used to move wafers between the bake and chill stations. Automated dispense systems apply chemicals to the wafers as they are spun in either the coat or develop stations. The bottom side of the wafer is rinsed with an appropriate solvent and a small amount of resist is removed from the top of the wafer near the edge for cleanliness.



Figure 2: Polaris coating tool



Figure 3: Remote chemical cabinet

The Polaris also has a remote chemical cabinet as seen in Figure 3. The remote chemical cabinet consists of a head case which contains electronics, the left wing which consists of resist bottles and is connected to the RSU (Reservoir Switching Unit), a RSU which holds the resists for the pumps and the centre cabinet which contains solvent pumps for the coaters. At the beginning of the coating process the coat module will send a signal to the RSU that is required resist. If the RSU is empty

¹ <http://www3.uic.com>

because the resist bottle is empty, contacts of the RSU empty relay will close. A signal is sent to the corresponding pump controller preventing dispense from the associated pump. On more than one occasions the RSU has failed on the detection of resist on the Polaris tool or the pump has introduced air into the resist lines and therefore cause scrap or rework due to poor dispenses and thus causes resist wastage. If the error is detected at the coater module the wafer can be reworked and if it not detected until a post-lithography metrology step then the wafer will need to be scrapped. The process can be improved by designing and implementing a second method for detecting empty resist bottles or air in the resist lines. By using a PLC and photomicrosensors, we can monitor sensors placed on resist lines at particular places to determine the status of the system using touch screen interface. In addition, by using PLC technology one can get remote access through web based applications from anywhere.

Ultimately, it is important to improve the dispense system on a Polaris coating tool because with the increasing cost of photoresist there is a need for less waste. There are more read/write heads on a wafer and larger wafers therefore if the Polaris coating tool has a poor dispense which is not detected and a wafer is scrapped, this will increase manufacturing costs. By reducing the amount of scrap and rework, there will be a reduction in the time to produce a single wafer thus reducing the overall production costs of making a single read/write head therefore staying more competitive in the hard drive market. The qualities of a PLC control system linked to the relay system is that there will be greater control of the dispense system at the chemical cabinet and at the coater module thus reduce the miss processing of wafer at the coater. We will be able to get more data from the remote chemical cabinet such as risk status and diagnostic information on chemical cabinet and resist line configuration. By getting this type of information the Engineers can view how the Polaris coating system is operating and enabling chemical handles to know when a resist bottle is about to empty thus avoiding equipment downtime. The controller will allow engineer and chemical handle get information by remote access from anywhere in the factory in real-time. Efficiency has become more important than ever, in today's global manufacturing environment as profit margins become smaller due to the global recession. This is why companies are

focusing more on improving the process of manufacturing through fab-wide process control system monitors can analyse differences in the machine process to detect errors. There is a need to gather more data and getting data in real-time and making it easy to access data. Compared to the relay system, PLC technology has the capability to make data more transparent and easier to access thus making it possible to interact with process control systems. This paper outlines our method for detecting empty resist bottles or air in the resist lines of a Polaris coating tool thus greater process control of the coating process by using PLC technology in conjunction with relays that are already used on the remote chemical cabinet.

2. Programmable Logic Controllers

Programmable Logic Controllers were designed in the 1960's with the request of an US car manufacturer (GM). The reason was to replace relay control systems (Vellano et al., 2007). The main problem manufacturers had with relays were that they were mechanical which meant that they were more likely to have maintenance problems and a limited lifetime. The other reason was the expense in replacing relay based machine control systems for carmakers in America. Carmakers like general motors wanted a device that could be programmed and reprogrammed and could operate in a harsh industrial environment (Chauvenet et al., 2010). The first PLC that was designed was named MODICON, which stands for Modular Digital Controller. Other companies designed their own version of the "new controllers" and finally in the late 1960's the PLC (Programmable Logic Controller) was created. It is a universal controller, which can be used for applications with whichever program, is loaded in the memory thus making it easy to change control processes. A PLC is a solid-state controller that consists of a stored program that could be reprogrammed when production requirements changed. As they were solid state devices that had a longer lifetime than relays and were able to control motors, sensors etc. thus making it less expensive when changing control systems in a changing industrial environment. The controllers were

programmed using “ladder logic” which was easier for the engineers to program, as it was similar to schematic drawing of relay logic. In the 1970’s there were more improvements made in the design of PLC’s which was that they were able to communicate with each other thus this meant that the controlling circuit could be a good distance from the equipment it was controlling (Amunrud, 2002). In the 80’s standardization in PLC’s was improved and also size of the PLC was reduced, thus space was used more efficiently. Until the 80’s, PLC were programmed using handheld devices or programming terminals and the programs were saved on tapes. Towards the end of the 80’s was the beginning of programming the PLC’s by personal computers using application software. From the 90’s PLC’s could be programmed using different types of languages such as C, instruction list or ladder logic. A PLC can communicate with a server thus getting remote access through web based application from anywhere (Holman, 2010). Different types of manufacturing industries are still using the Programmable Logic Controller.

In the generation of nanotechnology in semiconductor manufacturing there is an increasing role in advanced processed control and development. Given the shrinking feature size of a dye and process complexity there is need for tighter manufacturing tolerances to maintain project yield and reduce cost of producing wafers (Mouli and Srinivasan, 2004). One of the areas that process control is critical is lithography. In litho you have two main goals. The first is to place a pattern on the surface of the wafer and the size of the pattern is known as the critical dimension (CD). The second goal is to make sure that the second layer is aligned correctly to the previous layer, which is known as overlay (Martinez and Edgar, 2006). Thus process control is used to monitor both critical dimensions and overlay. Systems such as cell qualification, preventative maintenance and statistical process control alone are not enough to get the zero tolerance process that is required in the age of nanotechnology. The fab-wide process control system require that different PCS capabilities work together and that process control systems work in conjunction with non – process control systems such as yield management to address fab wide targets (Moyne et al., 2007) Also these solutions must be reconfigurable so that they can adjust to small changes in recipes

and other requirements in the present fabs to meet yield targets and output targets. A process control system can include statistical process control (SPC), run – to – run control (R2R), faulty classification (FC) and also fault prediction (FP). Some of the challenges facing a PCS system across all different areas in the fab i.e. lithography, etch etc are cost of software integration between different tool sets. Also another problem is data collection between PCS components and between process control systems and non process control systems. In 2001 a governing body for the semiconductor industry (SEMI) created a process control system task force to create interoperability standards for process control systems.

Run – to – Run control (R2R) is where recipe parameters can be changed or if there is a need to change control specifications between different batches of wafers (Gould, 2001). This is a method where process parameter changes are made using feed forward and feedback information. Controls such as critical dimensions and electrical device characteristic would be higher forms of run-to-run. Fault detection (FD) monitors analyses differences in the machines and process to detect errors and also there is fault classification (FC), which finds out the cause of the fault when it is detected. FDC is used at processed level to see any errors in process and also it can report back any errors in read time or it can repeat back their errors when the process step is complete. It can be used to check the health of run-to-run controllers and to help yield analyses. Fault prediction (FP) is where processed data is analysed so you can predict errors in the process thus avoiding equipment down time. This will be a very useful tool as the high cost of equipment in the semiconductor industry it needs to be utilized 100% of the time. Thus in the future fault prediction technology could be used in the semiconductor industry as it moves from a reactive approach to a proactive approach. Statistical process control uses statistical methods to check process of production specifications and take necessary actions to control and improve the process. It monitors errors like “out of control” errors. It can be used in all areas of the fab for monitoring specification and checking processed data from wafers. As the semiconductor manufacturing moves to smaller device sizes, there is a need for successful manufacturing plants to implement process control system standards. As

there is a greater amount of information generated PCS need to be able to quickly transform this data into information. There is also a need to constantly keep up with the changes in the process and machine communication by using process control system standards. With advanced PLC technology, machines states and alarms can be viewed from anywhere in the factory thus giving greater monitoring of equipment. PLC technology allows for more quality information to be gathered such as technical data and accurate real time data from the remote chemical cabinet. Finally, by using this technology there will be greater process control in the lithography area and thus cost reduction in the manufacturing of wafers

3. Problems in Detecting Empty Resist Bottles

The aim is to implement an alternative method to eliminate the risk of poor dispenses due to lack of resist or air bubbles in the resist lines as seen in Figure 4. Thus introducing another method for detecting empty resist bottles or air in the resist lines of a Polaris coater will reduce poor coating or non coating of the wafer. It will also reduce scrap and rework of production wafers, equipment downtime and reduce manufacturing costs. Improve quality and also improve the yield of a wafer and thus increasing through put by reducing downtime and to make sure that tool availability is over 80%.

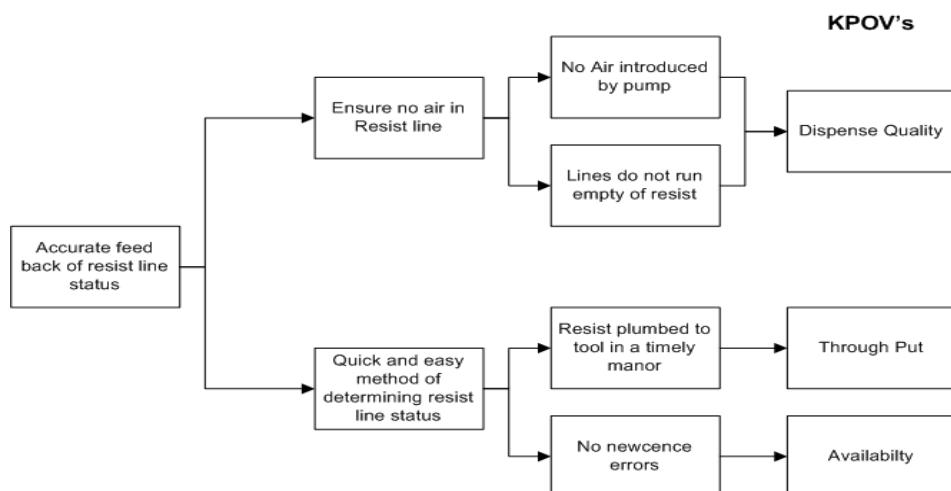


Figure 4: key Requirements

Each step in the existing process of the dispense system is analysed from the resist bottle in the remote chemical cabinet to the wafer that is being coated. When the Polaris sends a signal to the remote chemical cabinet that the wafer is ready for coating the following steps occur.

1. **Resist bottle:** called nowpaks as seen in Figure 5, these nowpaks hold resist and come in various sizes are placed in chemical cabinet and connected to the RSU. Chemical handler replaces it when RSU low level relay alarms.



Figure 5: Nowpaks

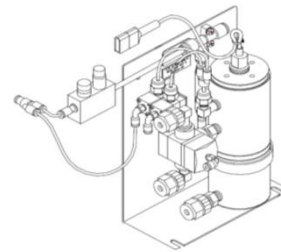


Figure 6: RSU (Reservoir switching unit)

2. **RSU:** RSU is reservoir for holding resist until requested by pump controller as seen in Figure 6. The RSU has an level sensor which alarms when the resist is low and thus allowing RSU to take resist from nowpak
3. **Pump:** When coater module sends signal to pump controller for resist the pump dispenses the correct amount of resist on wafer as seen in Figure 7.

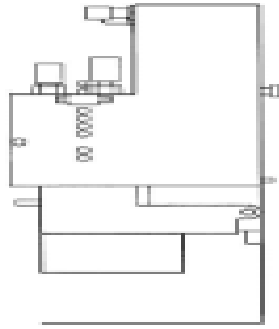


Figure 7: Millipore pump

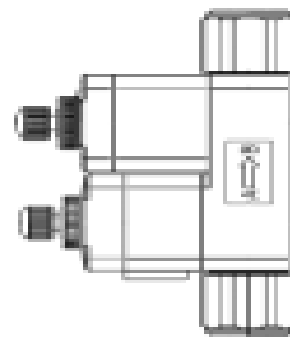


Figure 8: Suck back valve

4. **Suck back valve:** At end of dispense the suck back valve opens and sucks resist back into resist line as seen in Figure 8.
5. **Nozzle and dispense arm:** Used to dispense resist onto the wafer as seen in Figure 9.

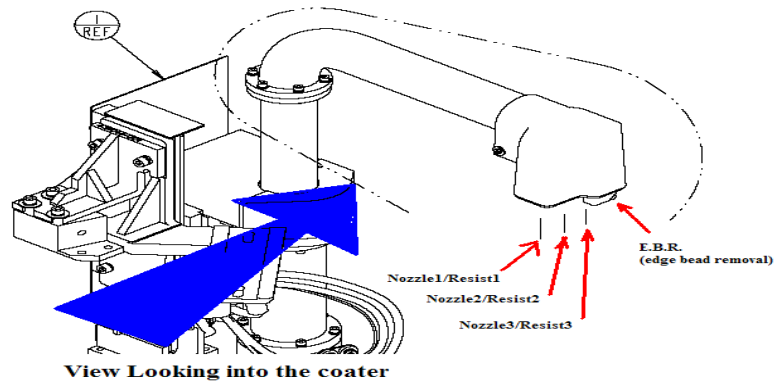


Figure 9: Nozzle and coater dispense arm

6. **Coater bowl:** This is where the wafer is held in the chuck and spins when resist is dispensed.

The biggest concern is the RSU and the method of detecting resist in the resist lines. The RSU level sensor has sometimes failed to detect that there is no resist in the

reservoir thus not alarming and failing to send a signal to the coater module to stop coating. Therefore coater module continues to coat and wafers are scrapped due to poor dispenses. There is no record of amount of times the RSU is refilled or an estimated time that a bottle of resist will last. The only way to check if resist bottle is nearly empty is to continually check the chemical cabinet. There is no mechanism to detect if there is an air bubble at the RSU output or at the nozzle side of suck back valve thus possibility of causing dispense variation effecting chemical coverage and uniformity thus causing scrap or rework. If the Polaris alarms for empty resist the only way that the chemical handler can be informed is by the operator and the only way to clear or check why Polaris is alarming is to go to the Polaris.

To see the effects and cost that this has on the coating process, we will equate the waste accumulated at this point of the process. Thus we will calculate the financial cost from wafers that were scrapped from Polaris tools over a 3-month period. As can be seen in Table 1 there were 38 wafers scrapped between December 2009 and March 2010 due to poor dispenses and no resist detected.

QTY	REASON	SDATE	SHIFT	ENG_COMMENTS	WS_ROUTE	TECHNOL
2	EQUIP	03/03/2010 23:49	2	BAD COT LOR RESIST PLR51 SCRAP WAFER		PHOTO
3	EQUIP	03/03/2010 23:48	3	BAD COT LOR RESIST PLR51 SCRAP WAFER		PHOTO
2	EQUIP	04/03/2010 21:56	2	BAD COT LOR RESIST PLR51 (RESIST RAN EMPTY)		PHOTO
3	EQUIP	03/03/2010 21:55	3	BAD COT LOR RESIST PLR51 (RESIST RAN EMPTY)		PHOTO
2	EQUIP	03/03/2010 21:55	2	BAD COT LOR RESIST PLR51 (RESIST RAN EMPTY)		PHOTO
3	EQUIP	03/03/2010 14:37	3	BAD COT LOR RESIST PLR51 (RESIST RAN EMPTY)		PHOTO
3	EQUIP	04/03/2010 00:41	3	BAD COT LOR RESIST PLR51 (RESIST RAN EMPTY)		PHOTO
2	EQUIP	04/03/2010 00:16	2	BAD COT LOR RESIST PLR51 (RESIST RAN EMPTY)		PHOTO
2	EQUIP	04/03/2010 12:59	2	BAD COT LOR RESIST PLR51 (RESIST RAN EMPTY)		PHOTO
2	EQUIP	04/03/2010 12:58	2	BAD COT LOR RESIST PLR51 (RESIST RAN EMPTY)		PHOTO
2	EQUIP	07/12/2009 22:19	2	WAFER MILLED WITH NO RESIST. SCRAP AS PER PROCESS OWNER.	395627	Photo
2	EQUIP	07/12/2009 22:19	2	WAFER MILLED WITH NO RESIST. SCRAP AS PER PROCESS OWNER.	395627	Photo
2	EQUIP	07/12/2009 22:19	2	WAFER MILLED WITH NO RESIST. SCRAP AS PER PROCESS OWNER.	395627	Photo

Table 1: Scrap events

To see the effects and cost that this has on the coating process, we will equate the waste accumulated at this point of the process. Thus we will calculate the financial cost from wafers that were scrapped from Polaris tools over a 6-month period. As can be seen in

table 2 there were 52 wafers scraped between December 2009 and March 2010 due to poor dispenses and no resist detected.

Taking the cost of a wafer when processed is \$2700 therefore 52 wafers have been scraped over this period. The costs of 52 wafers @ \$2700.00 each is \$140,400. This equates to average cost of \$280,000 financial waste per year. Given that the cost of hardware is \$4440 per Polaris therefore the total cost for 13 Polaris is just over \$57700. The possible savings when all Polaris have installed the new resist monitoring system is \$223,000.

4. Design & User Interface

We will describe the design of implementing a programmable controller into a polaris coating tool to improve the detection of resist in the polaris dispense system. The projected business benefit is that we have a good resist dispense which is critical to quality and will help to improve the yield of a wafer and also the time to market of hard drives. The main features of the PLC while working in conjunction with the existing dispense system is that it will enable the polaris to detect air bubbles in the resist lines and if a resist bottle needs changed, RSU level sensor feedback, touchscreen interface for tool status and resist details. It will also allow remote access through web based application from anywhere in the manufacturing plant. After consultation with equipment engineers and process engineers, the benefits of the PLC dispense system were discussed and a clear view of how the system should be designed and implemented were agreed. Figure 10 shows an operational overview of the operation of the PLC dispense system.

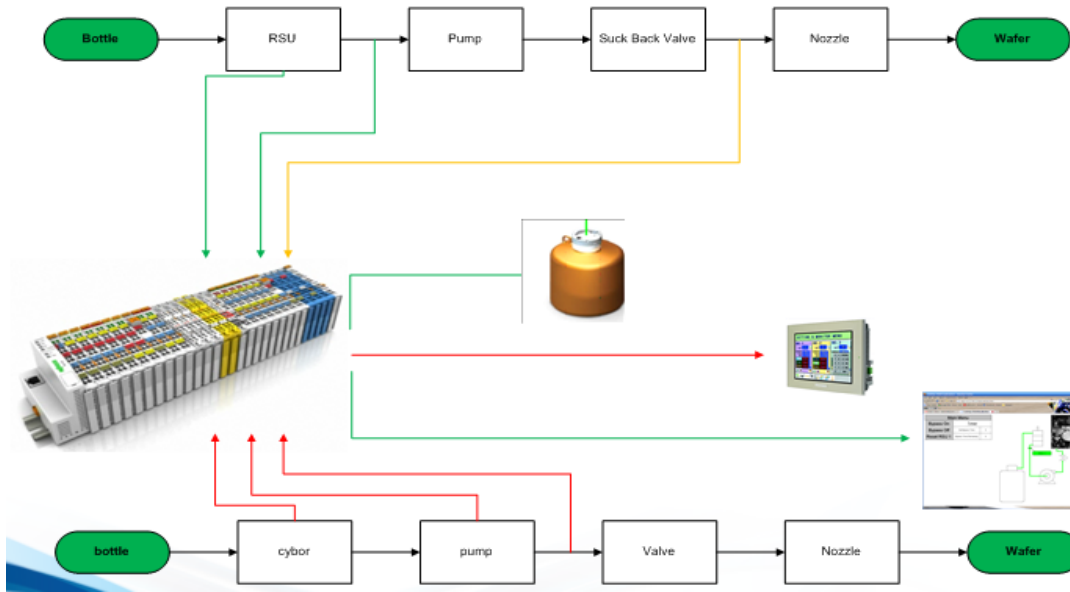


Figure 10: Control overview of dispense system

In the design phase we used controller development system software (CoDeSys) with the wago programmable logic controller to create visual charts of what is happening at the polaris in real time. Therefore the chemical handler or technician can visually monitor alarms on the dispense system as seen in real time as seen in Figure 11.

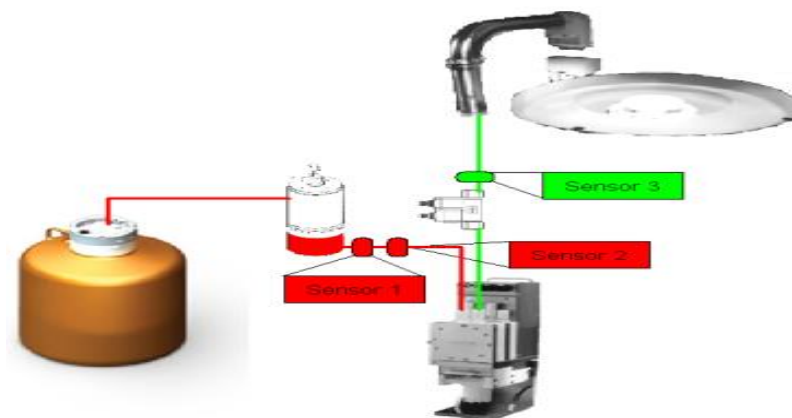


Figure 11: visual of RSU coater dispense

Controller development system software uses C language programming extensions so that it can create reusable code. The advantage of using object oriented programming language with CoDeSys software in the design of the dispense system is that the code for the application can be easily changed and if further development is needed the code can be extended therefore it is easily maintained. As with the dispense system for the polaris tools, the code may need changed for some polaris's as each polaris does not have the same amount of coater modules on its dispense system thus by using object-oriented programming the code can be easily modified to monitor any polaris in the cluster.

The user interface allows the chemical handler or technician to monitor the dispense system in real time and to respond to alarms in a timely fashion. Figure 12 shows the interface for the dispense system.

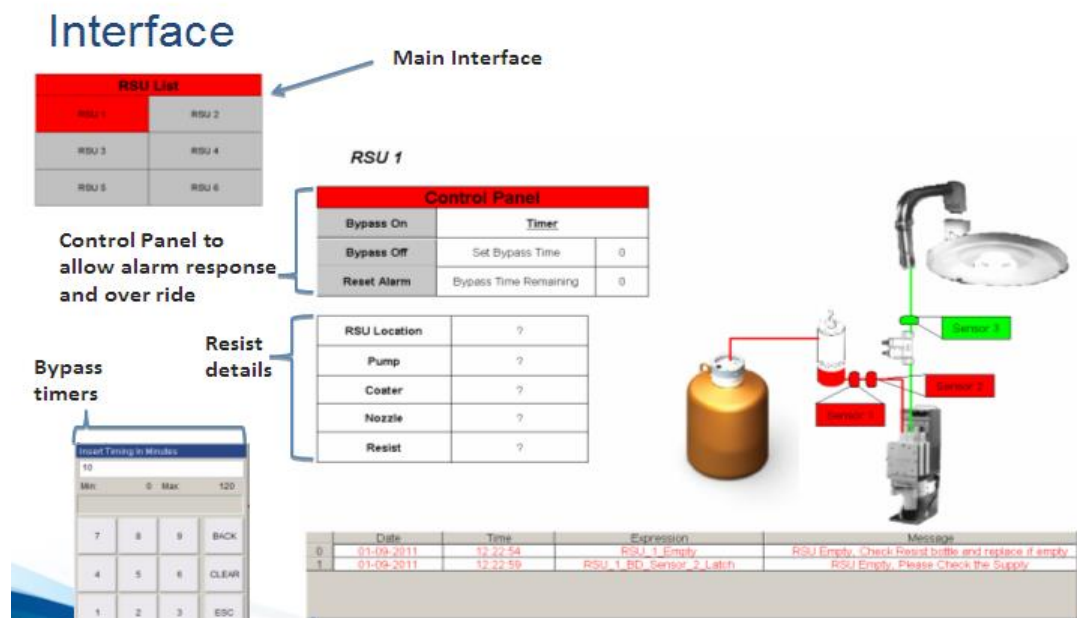


Figure 12: Interface for dispense system

The main interface (Figure 13) shows each RSU for the dispense system. The Control Panel (Figure 14) allows alarm responses and override.

RSU List	
RSU 1	RSU 2
RSU 3	RSU 4
RSU 5	RSU 6

Control Panel		
Bypass On	Timer	
Bypass Off	Set Bypass Time	0
Reset Alarm	Bypass Time Remaining	0

Figure 13: Main Interface

Figure 14: Control Panel Interface

The bypass timer allows the technician to set the bypass timer to complete work on the dispense system. The alarm log (Figure 15) gives details of the alarms on the dispense system.

	Date	Time	Expression	Message
0	01-09-2011	12:22:54	RSU_1_Empty	RSU Empty, Check Resist bottle and replace if empty
1	01-09-2011	12:22:59	RSU_1_BD_Sensor_2_Latch	RSU Empty, Please Check the Supply

Figure 15: Alarm Log Interface

The programmable logic controller is a Wago 750-881 which contains an Ethernet based firebus coupler with the PLC. This controller has many types of applications in the manufacturing industry. The 750-881 consists of a 2 port ethernet connection which can transfer real-time data within 1ms of the event occurring in the dispense system. It consists of a 32-bit CPU and also a web based management system for data storage. The advantage of using the programmable firebus controller in the design is that it can be used to remotely access the web based management system as seen in Figure 16 to monitor alarms and it allow the engineer to check the status of the dispense system when he is not at the manufacturing plant.

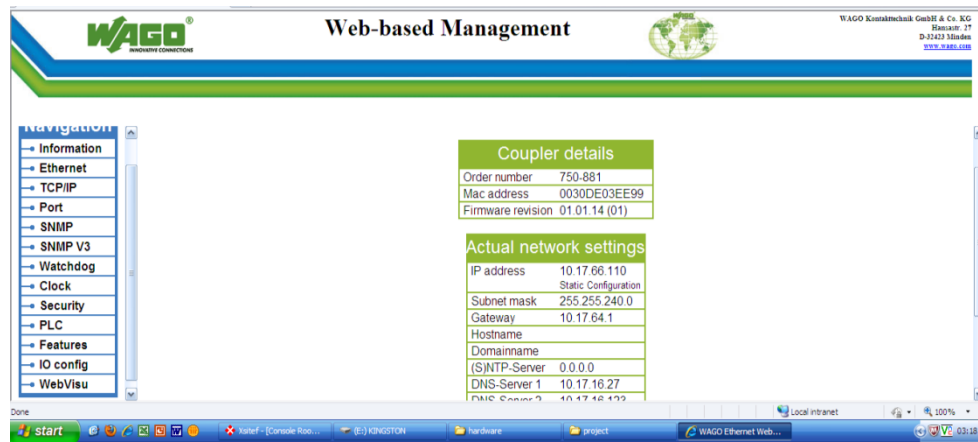


Figure 16: Web-based management system

In the dispense design, we used photomicrosensors (Figure 17) to monitor if there is resist or air bubbles in the resist lines. It is a non- contacting sensor, thus it scan sense the resist through the resist lines. The advantage of the sensor is it has a fast response time in sending a signal back to the PLC if there is an error in the resist line. It also has no mechanical parts thus the sensor has a long operating life.

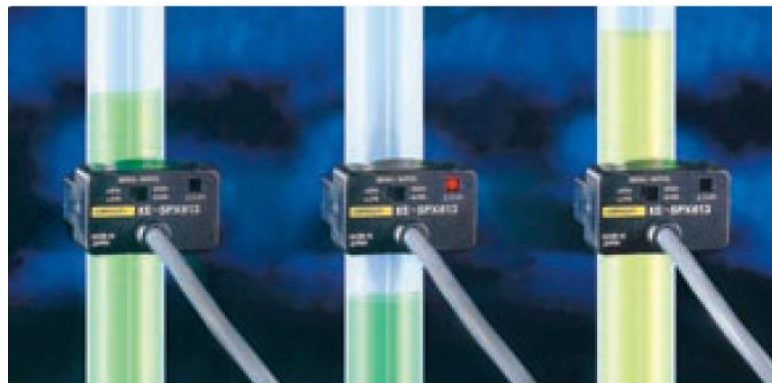
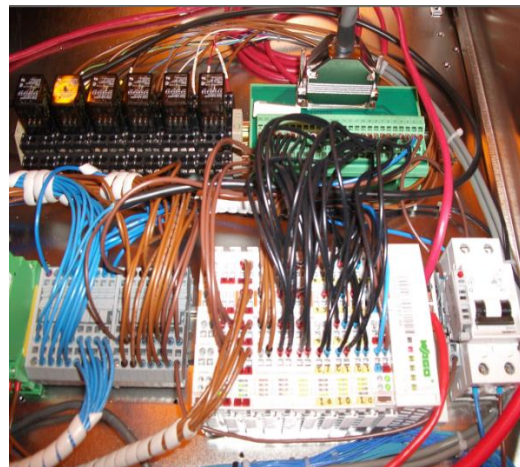


Figure 17: photomicrosensor

The Wago Touchscreen monitor was installed to the remote chemical cabinet so that the chemical handler or technician can monitor the interface of the dispense system for alarms.

5. Implementation

We outline the implementation of the PLC dispense system based on the data gathered in the design phase. First we will familiarize ourselves with some key images of the dispense system that are referred to throughout the paper. Sensor 1 and 2 are connected to the output resist line of the RSU's in the remote chemical cabinet and Cybor pump's² in the corner chemical cabinet. Sensor 3 is connected to the resist line connected to the dispense nozzle of the coater bowl's. The sensors cables are then connected to the PLC in the remote chemical cabinet. These sensors send a signal back to the PLC controller if any errors occur in the dispense system. The touch screen is connected to the remote chemical cabinet and an Ethernet cable is connected between the touch screen and the PLC (**Error! Reference source not found.**). The Resist empty relay is wired to the Program logic controller so that they work in conjunction with each other (Figure 19). All sensors and resist empty relays have now been connected to PLC, Touch screen has been installed and Ethernet connection to PLC. The IP address has been setup so that we have remote access to monitor the dispense system.



² <http://www.idi-cybor.com>

Figure 18: Touch Screen at chemical cabinet

Figure 19: PLC controller in chemical cabinet

Once sensors were installed in the coater modules, cybor pumps and RSUs and connected to the PLC, next we developed the code for each RSU and cybor pump so that the dispense system can detect if the resist needs changed or if there is air bubbles in the resist lines. If a sensor 1 or 2 is activated at the RSU or if sensor 3 is activated at a coater module, an alarm will indicate that there is a problem with the supply. The second latch looks for sensor 1 and 2 to be active at the same time as this would indicate a problem with the resist supply. Sensor 3 is connected to the resist line at the nozzle of the coater. The third latch is used to detect air bubbles in the resist lines between the suckback valve and the nozzle. A latch is required if so if a bubble is detected even for a split second the alarm will stay on. An alarm bypass function is required for technicians to complete work on the dispense system or else the tool will not allow the pump to operate and clear the lines. A latch is required so that if a bubble is detected even for a split second and drop the switch back back off. The second latch would look for sensor 1 and 2 to active at the same time as this would indicate that there is a problem with the resist supply. The third latch is looking for sensor 3 to be active as this would detect air bubble in the resist line between the suckback valve and the nozzle. A latch is required so that if a bubble is detected the alarm will stay on. An alarm bypass function is required for technicians to complete their work when purging the resist lines. If the alarm latch is on for either sensor then the main alarm will be switched on along with the corresponding alarms. PLC code was implemented to monitor the dispense system. The program will monitor resist lines to determine if liquid is present or if there is air bubbles in the resist lines and therefore control the alarms on the tool. A latch is also required so if a bubble is detected even for a split second the alarm will stay on and not drop back of.

5. Evaluation

The objective was to eliminate scrap by ensuring resist is always present in the RSU or Cybor Pumps and also to reduce scrap due to lack of resist or air bubbles in the resist line. Part of the motivation was also to introduce a more user-friendly interface for chemicals handler and technician to monitor errors on the Dispense System. The old interface is shown in Figure 20 while the new interface is illustrated in Figure 21. In the evaluation process we need to analyse how the new PLC Dispense System has met these objectives.

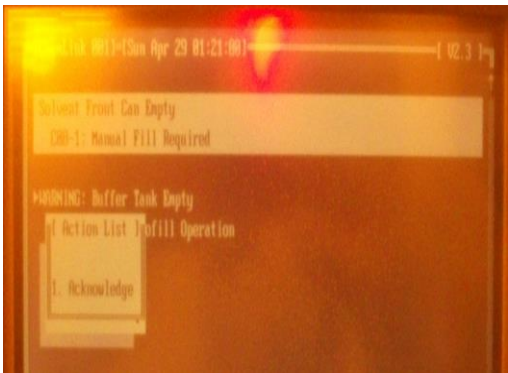


Figure 20: Interface for previous system

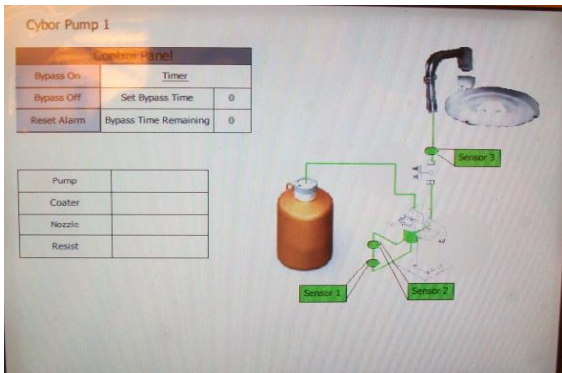


Figure 21 : Interface for current system

We can illustrate the functionality of the new system by a walkthrough. If an alarm occurs on the RSU while resist is being dispensed onto a wafer then the operator calls chemical handler as he has an error on the tool. The chemical handler checks touch screen at remote chemical cabinet (Figure 22Figure 22).

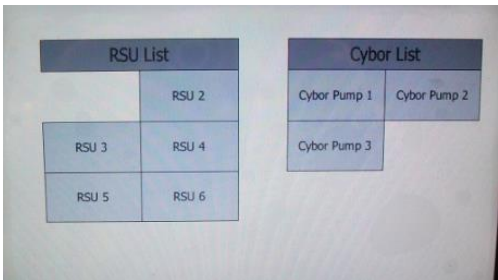


Figure 22: Touch screen



Figure 23: Main interface

The chemical handler sees that there is an error on RSU1 (Figure 23). Next, they check alarm log and see message “*RSU empty, check resist bottle and replace if empty*” (see Figure 24Figure 24) .

	Date	Time	Expression	Message
0	01-09-2011	12:22:54	RSU_1_Empty	RSU Empty, Check Resist bottle and replace if empty
1	01-09-2011	12:22:59	RSU_1_BD_Sensor_2_Latch	RSU Empty, Please Check the Supply

Figure 24: Alarm log

The chemical handler checks resist details on the user interface (Figure 25). They then replace resist bottle and clear alarm on control panel (Figure 26Figure 26). Polaris goes back to production.

RSU Location	?	Control Panel		
Pump	?	Bypass On	Timer	
Coater	?	Bypass Off	Set Bypass Time	0
Nozzle	?	Reset Alarm	Bypass Time Remaining	0
Resist	?			

Figure 25: Resist details

Figure 26: Control panel

The chemical handler and technician can now monitor the system from a remote station or a touch screen interface at the remote chemical cabinet. This makes it easier to monitor errors on the tool. The new interface provides visualisations of each RSU, Cybor Pump and Coater Module thus the chemical handler can view which pump or coater the error is coming from and what type of alarm it is by viewing the alarm log or the interface. With the new system the technician can set a by-pass timer so that he can complete maintenance work on the dispense system or coater module without effecting the other three coater modules therefore reducing downtime for the coating tool. Since each RSU and Cybor Pump has two sensors placed onto the resist line and

is working in conjunction with the existing relay system the detection rate has improved thus always ensuring that there is resist in the RSU's or Cybor Pumps. There is a sensor placed between the suck back valve and the nozzle where the previous dispense system had no detection method, therefore the rate of detection has increased thus preventing a poor quality dispense onto the wafer and avoiding dispense errors. There is a reduced amount of errors while the resist is being dispensed onto the wafer thus providing a more reliable dispense system and therefore a more consistent performance in coating wafer. As there are less dispense errors onto the wafer, there is less scrap and rework wafers thus this will reduce the amount of resist being used. As the cost of resist is one of the main manufacturing costs in producing read/write heads. A reduction in the amount of resist that is used will therefore reduce the cost of producing a read/write head. The dispense system now provides resist for the wafer in a pure reliable and precise manner from the source i.e. resist bottle to the wafer, because the resist is being dispensed in a uniform manner therefore quality has improved. The chemical handler and technician are more efficient in detecting where the dispense error has occurred and thus will also improve equipment efficiency. As there is less misprocesses and scrap and a more efficient dispense system, it has created process stability and thus there is more confidence in the quality of the coating system. Overall, there are less dispense errors, thus less rework and scrap, yield on the wafer has improved and therefore has reduced the cost of manufacturing a read/write head and also the time to market has improved.

To see the effects and cost savings that the new dispense system has on the coating process we will calculate the saving made due to the wafers that were prevented from being scrapped because dispense errors were detected before a poor dispense was put on the wafer as seen in Table 2.

polaris	WFRs	Alarm Description	Polaris	Eng Comment
51	1	Air and line at coater 1, noz2	Paused	Inspected OK
51	1	Air and line at coater 2, noz 1	Paused	Inspected OK
51	1	Resist empty detected	Paused	Inspected OK
51	1	Air and line at coater 3, noz 2	Paused	Inspected OK
51	1	Resist empty detected	Paused	Inspected OK

Table 2: Potential savings due to new system

To calculate the financial savings, if we take the cost of a wafer when processed is \$3,300.00 then we found that five wafers on the Polaris avoided being scrapped over a three month period which works out at $\$3,300 \times 5 \text{ wafers} = \$16,500$. Given the cost of new hardware = \$4,441.00 per Polaris then the savings for three months on the Polaris tool is $\$16,500.00 - \$4,441.00 = \$12,059.00$. The potential savings over twelve months is \$48,236. Due to the savings on Polaris, the company decided to implement the PLC dispense system on the twelve other Polaris tools. This could have a potential saving of $13 \times \$48,236.00 = \$627,068$ per year.

6. Conclusion

Efficiency in the semi conductor industry has become a top priority in today's global manufacturing environment as company's attempt to reduce production costs. This project aimed to develop a PLC system in conjunction with a relay system to improve the dispensing of resist onto wafers. Programmable logic controllers can be used for detecting if resist bottles are empty therefore they can also be used to view the dispense system from a remote station, tracking the amount of resist being used and improving the process by logging all the dispense errors. We initially looked at the lithography process and the system that is in place for coating wafers. We identified areas, which could be improved like the dispense system in which resist was not being dispensed

onto the wafer in a uniform way. This was because air bubbles in the resist line and resist running low in the RSU or Cybor Pump thus causing scrap and rework of wafers. There was a need to evaluate the actual cost of scrap wafers that has a bad resist coat. After discussing with the process and equipment engineers it was decided that a PLC in conjunction with the relay system would give a more reliable dispense system. The PLC system would allow a user friendly interface for the chemical handler and technician and this would be an advantage in trouble shooting dispense alarms. The programmable logic controller would allow for further applications to be installed to the dispense system that the relay system was unable to achieve. It not alone provides the technicians and chemical handlers a more efficient way of detecting dispense errors on coating tools but also provides engineers more feed back information on resist errors and allows them remote access to monitor dispense errors. Other departments such as process department to check quality issues can also use the information received from the PLC and materials department to check resist usage. Overall it will reduce rework and lithography and increase throughput of wafers in the Polaris thus providing confidence in developing hard drives. The main challenge was to provide a system that reduced scrap and rework thus improving process and quality and also reducing cost. Due to the success of the PLC control system and the savings, this system will be implanted across other coating tools in the company. Other benefits of course will come from the documentation of this reliable dispense system which may be replicated in similar processes.

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