Polymer Control in Aluminum Etch Chambers to Achive >450 hours MTBC

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Summary

Particle control is an important objective in **Al** etch systems. Unquestionably, Polymer buildup must be kept under control. Defects, which result from chamber flaking, typically bridge metal lines together, resulting in lower yield. Excessive polymer buildup requires a chamber wet clean, consuming manpower and equipment uptime. Currently, most metal etch process chambers in the world require a wet clean at 90 – 150 hours. This article will present measures to control polymer buildup,

and a qualification procedure to ensure the cleanliness of the chamber prior to running product. It will also show how Cypress Semiconductor has improved its metal etch mean time between cleans to 350-450 RF hours while improving yield.

Background

The use of **Al** for semiconductor wiring is very common in the semiconductor industry. In spite of the advent of Cu damascene, **Al** etch will dominate the interconnect market for the near term. **Al** wiring typically requires using barrier metal (usually **TiN** or **TiW**) to reduce electro-migration concerns. The etching of the barrier metal produces a relatively large amount of polymer in the chamber, as the etch chemistries used have a low selectivity to photo resist. Additionally, nitrogen is commonly used to control etch profile. Use of N2 unfortunately causes selectivity to decrease, resulting in faster polymer buildup. If left unchecked, this polymer will build up in layers on the chamber walls. The polymer is exposed to a heating-cooling cycle whenever a plasma is struck. Since the polymer has a different coefficient of thermal expansion than the chamber walls, stress cracks eventually appear in the polymer, which leads to polymer flaking. Control of polymer buildup is the key to metal etch chamber cleanliness.

At Cypress, we etch a variety of metal stacks using the LAM 9600 stand alone CE and CFE platforms. The systems consist of an entrance load lock, a standard E-chuck process chamber, a water vapor DSQ plasma load lock, and an APM module. **Ti** is used for local interconnects, while a **TiW/Al/TiW, TiW/Al/Ti,** or **TiN/Al/Ti** stack is used for global wiring. All of these stacks contribute to, and can be negatively affected by polymer buildup.

At the start of this project we were seeing an MTBC (Mean Time Between Clean) of 70-90 RF hours. This amounted to a wet clean about every 10 days (See Figure 1). The number of wet cleans have gone from 2.7 wet cleans per month per tool to .7 wet cleans per month per tool. Another way to measure the improvement is the Maximum Time Between Cleans, which went from ~200 RF hours to over 500 RF hours. The system's main failure mode was particulate failures and at least one production lot per quarter was being scrapped with bridging metal as the cause. In addition, defect density counts were reduced by more than 50% due to the improvements made (Figure 2). Between all of the particle failures and wet cleans that were occurring, the availability to production was at an all time low of 60% to 70%. (See Figure 3)

Results

A cross-functional team was initiated which included the maintenance supervisor, the etch engineering tool owner, the etch engineering supervisor, and several line maintenance technicians across all shifts. The team met daily and reviewed all particle charts and excursions. Pictures were taken of chambers right after opening and the best performing systems were compared with the worst performing systems to try and pinpoint differences. Polymer flaking was observed in the process chamber, on the entrance load lock inner door, the endpoint window, and turbo manifold/vat valve area.

Entrance Load Lock Cover

To eliminate the flaking on the entrance load lock inner door, we installed the heated entrance load lock door upgrade. By putting the heater on its highest setting we were able to virtually eliminate the buildup on the ELL inner door. This took care of our first area of concern. Temperature measurements of the ELL inner door were taken with various covers on the entrance load lock. With the heated entrance load lock cover from Lam Research on its highest setting a reading of 85C was measured on the inner door. With a Galiso heated ELL cover a reading of 81C was measured on the inner door. Both versions of the heated ELL covers are made of mostly aluminum. An aluminum cover on the ELL with no heaters turned on measured 68C on the inner door. With the standard lexan cover on the ELL, the inner door measured a temperature of 48C. Either heated ELL cover works well in eliminating the ELL inner door as a cold source for polymer flaking. Cypress uses one type of heated load lock cover because it is a simpler design, less expensive, and works the best with the other upgrade items.

Heated Endpoint Window

The next area we pursued was the endpoint window. This was always one of the worst areas for polymer flaking. We would also see a rapid degradation of the endpoint signal at 70 – 80 RF hours. On the original endpoint window, , it was noticed that the least amount of polymer was in the area of the endpoint tubes (the only heated area). We developed a full window heater for the endpoint window that covers the entire window. This heater is ramped up to 80C and the polymer buildup has been virtually eliminated. We have also found that with this heater in place we can also achieve over 450 RF hours without degrading the endpoint signal out of its range. With the entrance load lock doors and the endpoint window heater installed, we saw our MTBC rise from the 70-90 RF hours to the 90-100 RF hour range.

Turbo Manifold and VAT65

Another area of flaking that we concentrated on was the turbo manifold/ vat valve area. The bottom of the turbo manifold was cooler than the rest of the manifold and chamber. The heater blanket around the manifold would "sag" a little and not make good conduction to the manifold. Clean room packing material was a very cheap and simple fix to this problem.

Particle tests which cycled the Vat Valve were completed and it was found the current Vat Valve installed on the 9600 systems was a particle generator. We also noticed a number of the production lot bridging metal failures were partial bridges that fell on during a step change in the etch. This was a spot in the process where the Vat Valve would have been moving to change the pressure in the chamber. The original vat valves on the systems were Vat 64 valves. These valves have an actuating system which made it difficult to control pressure on our etches. The presets on the valve always needed adjustment and the Vat 64 valve was difficult to clean and PM. We then tested the VAT 65 valve. This valve has a pendulum design, is easier to clean, and eliminates the need for presets. We have found only one source of particles from it. The dynamic O-rings in the rotation housing tend to wear quarterly. We change the O-rings out on a Quarterly basis and have not seen this problem return. The Vat65 changes brought us up to 125 hours MTBC on average. With the above changes in place, the main failure was still particles and the chamber would still have massive flaking failures.

Hot Gas Sweep

Too much unstable polymer was being put on the chamber walls. Other options were looked at. One approach was to perform a plasma clean on a regular basis to remove the buildup. Ideally, an oxygen plasma would be used, since the polymer is organic in nature. This was not an option since O2 was not plumbed to the chamber, and all of the available gas ports were in use. An **N2** plasma was also tried. It was not effective enough to justify the loss of throughput it required.

We then tried the hot gas sweep (HGS) system. It was already in trial at a few customer sites with some success. We tested the HGS unit on the worst performing system. The hot gas sweep unit consists of a special pump, which is plumbed with **N2** or **Ar**. The compression in the pump heats the gas and creates a viscous flow. The viscous flow then “breaks off” the polymer spikes and pushes them down the pumping line, leaving a more robust deposition surface for the polymer to adhere to. The goal for the HGS implementation was to increase from 125 RF hour MTBC to 250 RF hour MTBC.

System requirements had to be met. It had to be an automatic system. No maintenance or other personnel are needed to start or finish the sequence. An operator is able to start the HGS process every time it is needed, by starting a particular recipe, and HGS ends on its own. The system also had to leave the Lam 9600 in a production ready state where production wafers could be run immediately. It needed to also eliminate the buildup on the chamber, which caused the massive polymer flaking.

The first version of the HGS was a process chamber side-mounted system with the connection being on the “modified” leak check port. The system has a PLC control and was able to start and end the sequence by selecting a recipe. The first requirement was met. Different scenarios were tried and we realized we could not open the ELL inner door while sweeping. We “dusted” the ELL by opening the door causing a wet clean. The modified leak checker port was another problem since it was now unheated and hard to clean. Particle checks were still failing periodically and the leak checker port was the problem area 85% of the time. Yield from our HGS tool was compared with the best non-HGS performing tools in terms of particle counts. The HGS tool was 4%-5% better in yield. It also showed a significant number of lower single column defects on product wafers that are a measure of metal bridging. The first version of HGS brought the MTBC into the 150-175 RF hour range. A different design was needed other than the current one to get 250 RF hours.

Phase II HGS ended up being the final design. The design includes a modified heated ELL Cover from which has the HGS unit hooked up to it. The entrance load lock is “swept” first. The main chamber and DSQ areas are done in order, and we follow up with the entrance load lock once again. The sweep is done twice a day and takes about 20 minutes each time. The heated leak rate ports were put back on the process chamber excellent results were achieved. Some systems reached 250 RF hours. There were some mixed results as well.

When we started to investigate the early failures on the systems and found that inner door leaks and chamber integrity were adding to our difficulties. On top of that we were starting to see some “false” particle failures from the DSQ plasma load lock area. These particle failures are considered false because although they added particulates, they were known not to cause yield failures on the wafers.

O-Rings and Parts Cleaning

We found that the Chemraz O-rings we were using on the inner door surfaces were too elastic when heated. They lost their shape too easily causing leaks. We switched to a Viton O-ring which was able to hold its shape, and the particle performance remained the same. The Viton O-ring is changed every wet clean. We went from using a $400 O-ring on every wet clean to using a $2 O-ring on every wet clean and getting better leak performance.

Vacuum integrity was also looked at. The spec was always <3mt/min rate of rise on the process chamber with the load locks vented. It was recommended that we try a spec of <1mt/min ROR before seasoning the equipment. To save time, a helium leak check of both load locks and the process chamber after every wet clean was implemented. The <3mt/min ROR specification remained in place. This ensures that the chamber is leak tight before seasoning the system. It also enables us to find leaks while the system is still outgassing, saving valuable hours of troubleshooting leaks.

Cleanliness of the chamber ceramics is always a concern. The old procedure is to put the dirty ceramics in a Hot DI bath, scrub them with Scotch Brite, put them in a megasonic bath with Hot DI for about one hour, and then rinse them and put them in a 100C oven. We introduced the Hot DI bath/scotch brite scrub to remove the initial polymer and then took them to a ceramic shop to be kilned. We then brought them back to our plant and gave them a final megasonic bath/ hot DI wipedown and placed them in the 100C oven. The kilned ceramics came back looking brand new and give a much better starting point for polymer adhesion than the old way of just scrubbing the parts. We not only passed the 250RF-hour plateau, but soon went over 300RF hours.

Defect Quals

The particle qualification is not foolproof and can show good particles in spite of bridging being present. We had one case after a wet clean where the particle qual passed nicely, but we failed bridging measurements on product wafers. The particle qual is performed on a blanket TEOS wafer with plasma on in the Main Chamber and the DSQ. This is done to mimic the product process flow as closely as possible. To eliminate the undetected failure, we instituted a full stack defect qual post wetclean which ensures starting with a known clean chamber. It greatly reduced any premature wetcleans. Product is also sampled for bridging defects on a KLA system with automatic defect classification during the cycle between wet cleans. The samples ensure the system is healthy during the entire cycle.

DSQ and APM Modules

Non-yield affecting particles are also found in the DSQ area. These defects are stripped away, but do cause unnecessary downtime while the root cause is being determined. One cause for the defects is the quartz chipping that occurs. The current design allows the quartz to “rattle” while pumping down and venting. Putting teflon inserts into the DSQ solves this issue, which restricts the movement of the quartz. This change saves Cypress about $16,000 per quarter in Quartz replacement costs. The next cause of particulates in the DSQ chamber is the upper DSQ O-ring. Kalrez O-rings flaked and needed replacing about every 150 DSQ RF hours. Flourosilicon O-rings last longer and are significantly lower cost.

The Final Configuration

Since implementing these changes to the 9600 systems we have had system performance exceed 500 RF hours between cleans. We also have not seen a production lot scrap for metal bridging defects caused by a 9600 etcher for over one year. We have systems which have gone from 10 days between wet cleans to over 70 days between wet cleans running 24 hours/day seven days/week. The uptime has gone from a low 60% - 70% to a respectable 85%-90%. The cost savings in maintenance time, yield increases, and uptime performance has led to an ROI on these changes of less than 4 – 6 months depending on the results seen.

Cypress' 9600 metal etcher recipe for success:	
Main Chamber	
-Phase II HGS unit	$70,000
-Fully Heated Endpoint window	$1,000
-Packing material under turbo flange	$0
-Vat65 valve upgrade	$30,000
-Viton Door O-rings	$ (398)
-Vat Housing Quarterly PM's	$5
-He Leak check the system after each clean	$0
-Kilned ceramics	$75 per kit
ELL	
-Heated entrance load lock cover	$5,000
-Weekly ELL wipedowns	$0
PLL (DSQ)/APM	
-DSQ quartz inserts	$100
-APM N2 filter upgrade	$2,000
Total Changes to System	$100,000

We have found that each of these items brings some success, but to start achieving over 400 RF hours MTBC it takes doing all the items to achieve it. Moisture and temperature are still the biggest enemies of a metal etcher. Control the moisture and temperature and you control the majority of the polymer deposition and system stability.

Tables and Figures

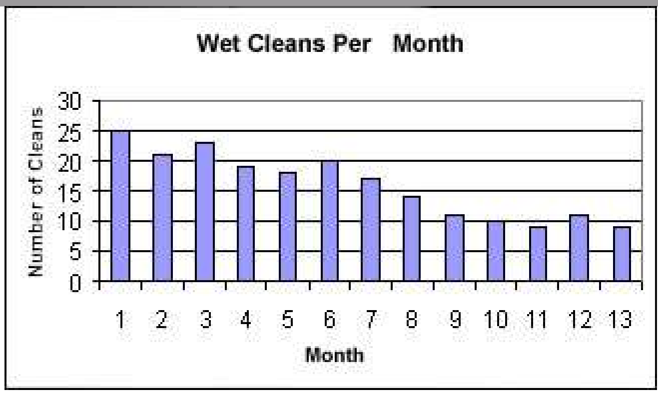

Figure 1 - Wet Cleans per Month

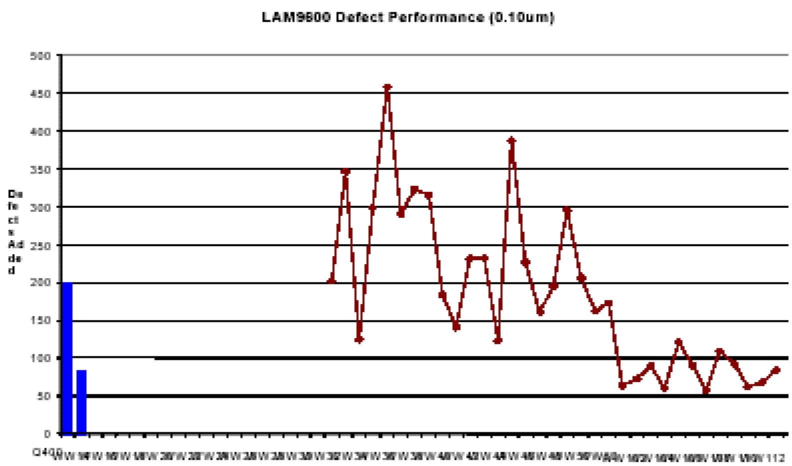

Figure 2 - .1u Defect Performance

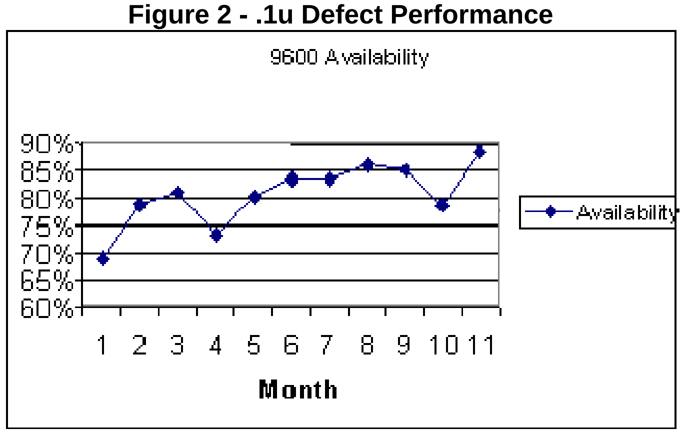

Figure 3 - System Availability

AUTHOR BIOGRAPHY

Robert King is currently a maintenance supervisor with Cypress Semiconductor in the photo and etch areas. He received hisBachelors Degree in Electronic Engineering Technology from the DeVry Institute of Technology and his Masters of Business Administration from the University of St. Thomas.