Improved Availability for Copper Plater Tools

Patrick Santos, Jens Riege

Skyworks Solutions, Inc., 2427 Hillcrest Drive, Newbury Park, CA 91320,
Patrick.Santos@Skyworksinc.com, Jens.Riege@Skyworksinc.com

Keywords: equipment, repair, maintenance, availability

Abstract

The wafer backside copper plating process at Skyworks provided a new set of challenges and learning curves. Equipment/Process Engineering and Equipment Techs have made huge strides to optimize the tools' performance to reduce tool errors and increase uptime for maximum throughput.

INTRODUCTION

With the release of the new Copper plating process to our Newbury Park facility, we faced a variety of road blocks. In particular, keeping our Cu plating tools running consistently without errors was challenging. A lot of this attributed to lack of knowledge of the Cu process itself. The combination of process knowledge and equipment set up are major factors for optimal results.

FAILURE PARETO

To drive equipment improvement, we analyze the top equipment issues and track weekly. We then attack the top items to drive increased availability. Failure modes related to wafer oxidation consistently have been our top failure Pareto for the copper platers. (Figure 1).

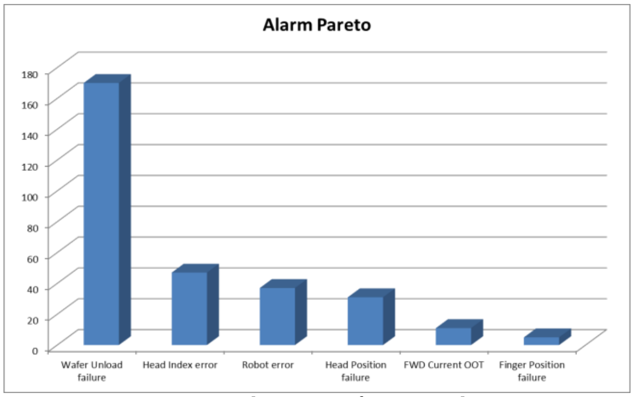

Figure 1. Alarm Pareto for copper platers

WAFER OXIDATION

Copper oxidation occurs within minutes when a plated wafer is exposed to oxygen in the air and even faster if the wafer is still wet or damp with copper bath solution or DI water. There are different degrees of wafer oxidation depending on the amount of time the wafer is idle. Figure 2 shows some examples.

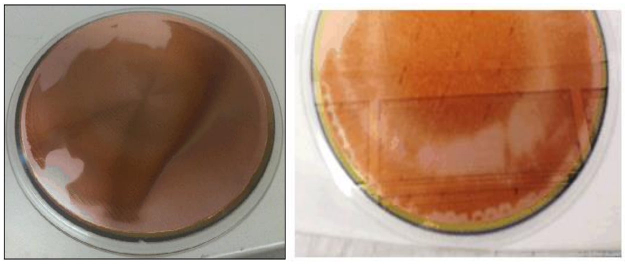

Figure 2. Wafer oxidation over time

ROOT CAUSES

In order to fix this problem we first had to understand the root causes for wafer oxidation. There are several components that we found contributing to wafer oxidation.

1) Equipment wafer handling.
    - Handling on our single wafer processing tools is affected by Cu contamination in the form of crystal buildup on the robot end effector. Contaminants prevent wafers from making vacuum as they are pulled from plating chambers, causing tool alarms.
2) Improper wafer rinsing
    - Each wafer needs an adequate rinse after plating.
3) Laminar air flow or Exhaust
    - Wafers exposed to air without the proper rinse will oxidize.

HANDLING ERRORS

By drilling down, our most common equipment failure mode was “Wafer Unload Failures”. These errors result from Cu contamination on the robot end effectors.

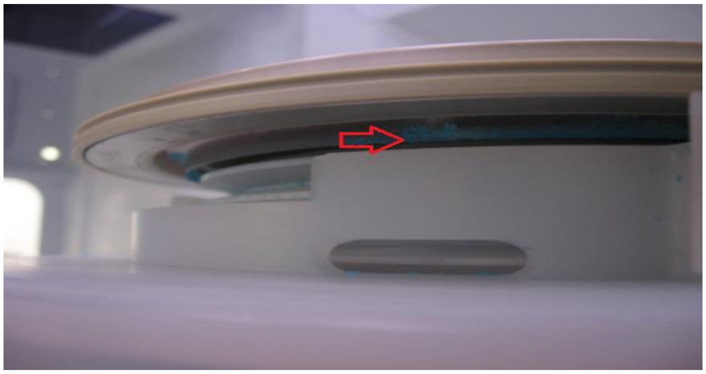
Figure 3. Cu crystal build up

The Cu solution now in crystal form (Figure 3.) would build up under the wafer ring seal and eventually find its way on to the end effector as it goes to retrieve the wafer. This will cause improper vacuum and inhibits the tool’s automation, leaving the tool in an idle state until the problem can be acknowledged. Even though equipment support responds quickly to these events, the wafer is already oxidized before they can get to the tool.

Another casualty from the Cu contamination is the damage to the robot end effectors (Figure 4.) Over time we have seen the robot end effectors deteriorate from Cu exposure to the point where the end effector seals become damaged.

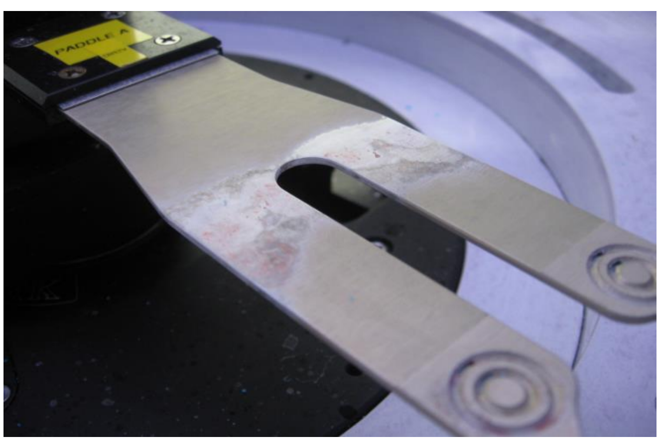

Figure 4. Effect of Cu solution attacking the aluminum end effector

To eliminate the spread of the Cu solution, more stringent PMs were put in place. We now require daily cleaning of the ring seals.

In addition, a ceramic end effector is now used to withstand the exposure to the Cu solution (Figure 5).

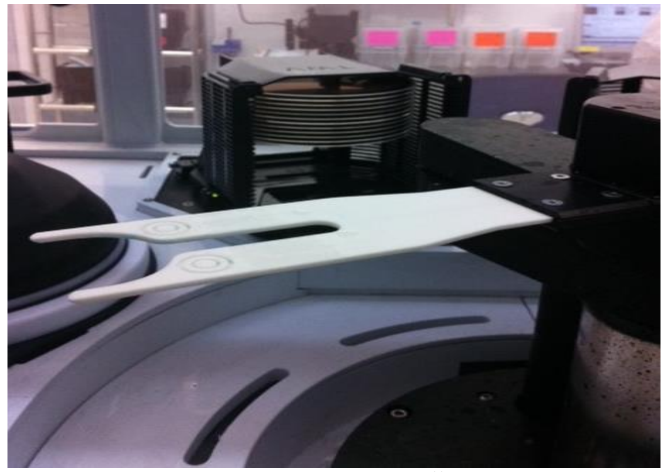
Figure 5. New ceramic end effector

Next we addressed the root cause for the crystal build up. We found this was due to improper positioning of the Z-axis when the head is in the closed position. We found in some cases that the close position is set too deep in the Cu solution. This causes the Cu solution to get on back of the ring seals. As the heads open, this causes a “scooping” effect.

Because of the design of our tool we do not have the ability to see the depth of the wafer in the solution with the head closed (Figure 6). Instead, we had been relying on a trial and error method to ensure the wafer comes in contact with the bath meniscus for optimal plating. In most cases we either over compensated or caused damage to the tool.

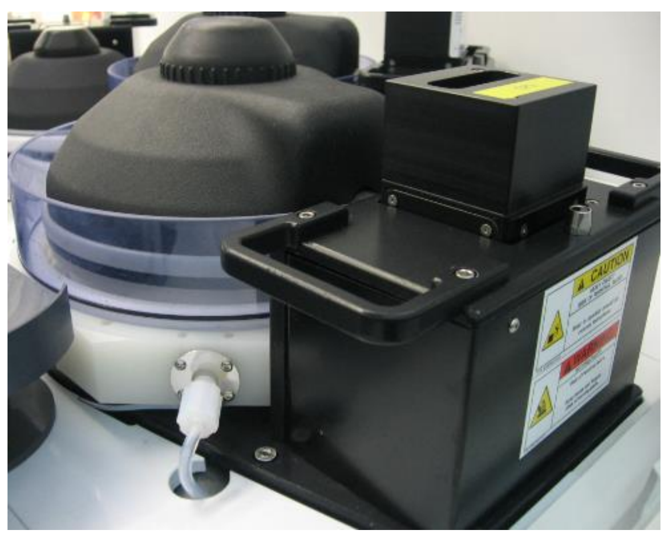

Figure 6. Head position CLOSED

To eliminate the guess work, a Pyrex fixture (Figure 7.) was made to help us find a depth height reference point.

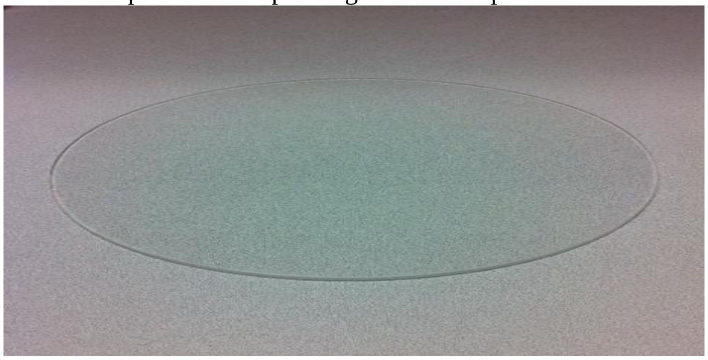

Figure 7. Pyrex fixture

The Pyrex fixture is placed inside the chamber on top of the diffuser plate assembly and acts as a hard stop when setting the close position. This ensures that the wafers (when in the closed position) are not too deep in the solution. As a result we can dial in our specs with ease and prevent Cu solution from spreading to the backsides of the ring seals.

WAFER RINSING

Wafers are rinsed after plating in the same chamber, using an “in situ-rinse” step. If wafers are not rinsed properly we can 1) oxidize the wafer, 2) dilute the Cu bath with rinse water.

In order to accomplish an optimal rinse, the DI stream needs to hit the wafer (as it spins) and deflect the water into a bowl weir and not into the bath. To accomplish this it takes a combination of nozzle angle and head height adjustments (Figure 8).

After understanding this factor, the proper adjustment method was documented. Accurate rinse setup is now verified during monthly PMs.

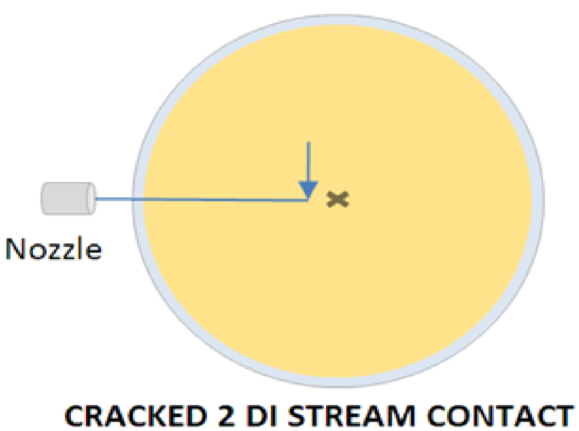

Figure 8. Shows DI stream target for optimal rinse.

CABINET EXHAUST

After plating copper in the plating head, each wafer is rinsed in-situ using a small stream of deionized water to remove most of the plating solution from the surface of the wafer. We learned wafers would oxidize to an orange color in less than 20 seconds after being unloaded from the plating head if the in-situ rinse was not set up correctly. After that, plating wafers are loaded into the rinse head for thorough rinsing and drying. However, oxidation continued on the dried wafers to a dark brown color as completed wafers sat in an unload cassette waiting for the rest of the lot to finish plating.

The plating cabinet design provides significant laminar flow across the upper cabinet deck because this cabinet is designed for a variety of end uses and materials such as strong acids and bases and solvents. High laminar flow is not required and is detrimental for a copper plating bath. The upper cabinet was designed with louvers that can be closed to block air flow. Unfortunately, plastic does not easily hold its shape, and significant air flow still made its way through the gaps. When we fully blocked the air flow, oxidation was significantly reduced (Figure 9).

Figure 9. Plating cabinet and louvers to block air flow (circled).

The combination of all three changes has improved our wafer handling and minimized the number of wafers impacted by wafer oxidation related events as shown in (Figure 10.)

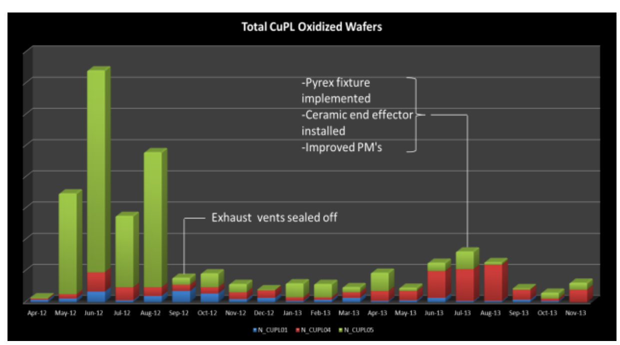

Figure 10.Trend chart

Conclusion

By using a Pareto analysis, identifying root causes, and taking corrective action on highest Pareto items, we have been able to significantly reduce the number of wafers affected by oxidation on our Copper platers.