Successful GaAs
Backend Process Improvement

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Abstract

A successful GaAs wafer breakage reduction strategy is described. A systematic approach was used to understand the many factors that cause wafer breakage. Problem solving methods, including Six-sigma methodologies led to understanding of the grind process, and some surprise causes of wafer breakage. A data-driven decision making process is used to determine the major causes of wafer breakage in the grind process, and to reduce wafer breakage by 95 percent over the period of investigation.

INTRODUCTION

This paper examines detailed wafer breakage reduction strategies employed by the Skyworks Wafer Fab Backend Core Team. Similar activities might be employed at another GaAs wafer fab to reduce wafer breakage and increase line yield. Case studies of our most interesting and successful findings will be presented.

DESCRIPTION OF PROBLEM

In September and October of 2009, we experienced a spike in wafer breakage at the GaAs grind process. The weekly breakage rate exceeded 10 percent for some weeks. This breakage resulted in scrap, since there was no mechanism to continue the broken wafers through the remaining process steps. A cross-functional team was formed, with operations, EHS, facilities, process, equipment, and quality engineering.

The team looked at process commonality. There was a commonality of higher breakage on some substrate lots. Further analysis of the suspected boules with an infrared grey-field polariscope showed an anomaly "the line". (See Figure 1) The breakage was always a horizontal crack in the same location as the line. This was an interesting finding, but the team realized that implementing a screening process would not be a manufacturable solution, and moved on to the realization that we had to develop a process that would overcome substrate stresses.

Infrared Polariscope Image of Stress Line

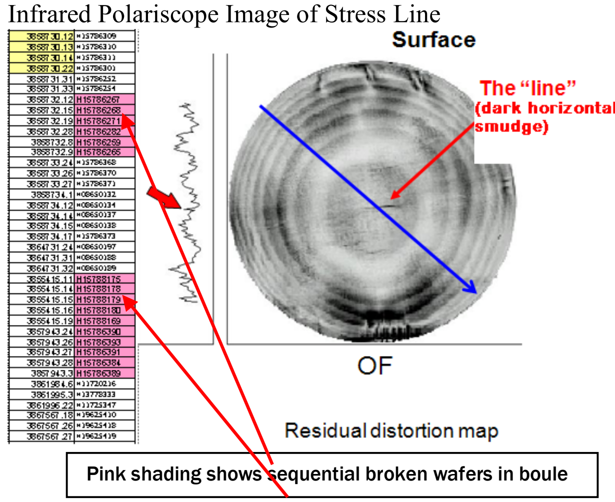

Figure 1: Infrared Residual Distortion Map

IMPROVEMENT METHODOLOGY

We looked at the data currently collected on breakage, and realized that it was not precise enough to help us solve the problem. A new data-collect system was designed and put in place 9/09 to automatically populate a database with breakage events at grind. We set up data collection at eight points in the backend process flow, with six categories of breakage types, and a "not broken" category as well. The data is extracted from our MES and added to an Excel database. This data can be analyzed in a number of ways to determine if there is an increase related to a tool, operator, or breakage type. Breakage data is published and reviewed daily. The new data collect allows us to have good visibility of the type of breakage, and at what point in the backend process flow it occurred. By focusing on the causes of each type, we were able to implement solutions to reduce or eliminate the breakage. As an example of the use of this data, the next page shows charts of a breakage summary by type during a week and rate of breakage for a particular type over time. Detailed descriptions of the investigation, result, and improvement strategies for each breakage type will be given during the presentation

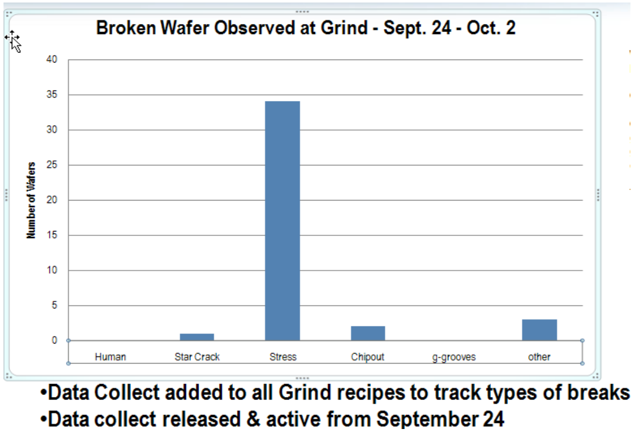

Figure 2: Breakage Summary

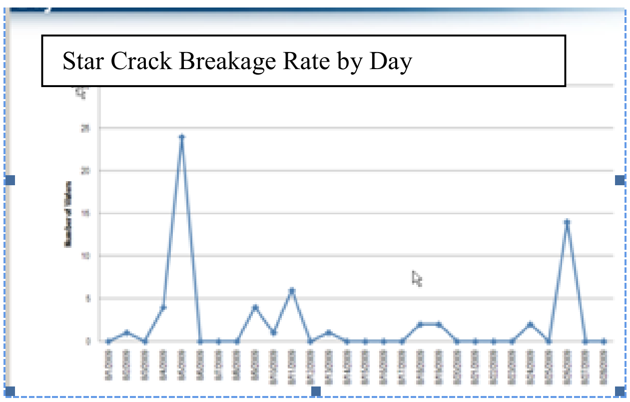

Figure 3: Star Crack Daily Breakage Rate

Figure 4 below shows a "star crack" and the chart above shows breakage rate, with spikes of up to 25 wafers/day. Star cracks were traced to a particle contamination on a robot transfer arm. When a particle attached to the arm, it would cause a crack on subsequent wafers in the run. Initially we focused on detection and containment. This included frequent transfer arm PM, and equipment changes to use only DI water for the arm cleaning. We also modified the cleaning nozzle pattern to provide a higher pressure, focused spray to the arm pickup area. We then worked with the vendor on prevention, and installed an automated transfer arm cleaning station that cleans between each wafer. Star cracks are no longer an issue. We now see less than one star crack per week.

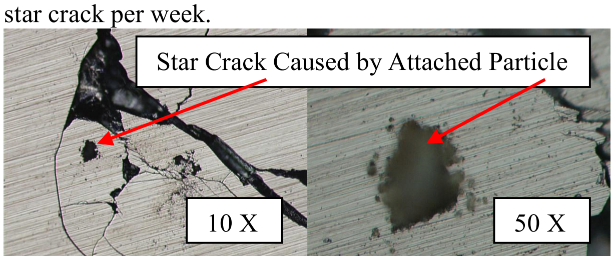

Figure 4: Star Crack Image

The team was relentless in determining causes of breakage. In this quest, we looked at these factors:

- Investigate table angle effect on grind breakage. Table angle is a critical parameter that affects the down force of the grind wheel, and can also cause variable stress patterns across the wafer that affect breakage rate. Having the correct table angle is a necessary starting point.

- Investigate impact of recirculating/filtered grind water chemistry on grind process. We use a filtered, recirculating loop to supply water to the grinders. We found that breakage events closely followed filtration system maintenance events. The process of record was to periodically replace 300 gallons per week with DI water. When that much water was added, we noticed a correlation with degraded grind performance. We also had a PM process that used a GaAs etchant to open up the clogged pores on the grind chucks. The effect of both the etchant and large adds of DI water is to allow the ground GaAs to go into solution, rather than suspension, making it difficult or impossible to filter. We believe the water chemistry change altered the surface tension, affecting the wetting of the cutting water. We switched our process to adding the DI water gradually, ½ liter at a time, every grind run, and eliminating the chemical etching. When we got rid of the large water adds, and the etchant PM, our grind process and filtration costs improved dramatically. The grind breakage rate stabilized at 0.5-1.0 percent.

- Investigate grind parameters with DOE, analyzing break strength data and the grind wafer breakage results. We made a permanent change to our grind parameters, slowing the removal rate for both coarse and fine grind, and reduced the amount removed by coarse grind and increased the amount removed by fine grind. This change allowed us to be consistently below 0.5percent.

- After this, we continued to improve the grind breakage rate by qualifying a new "low stress" grinding tape. This tape is marketed as having no dimensional changes during the UV exposure, and our observations supported this claim. There was visibly lower post-grind and expose warp and bow using this tape. This change allowed us to be consistently below 0.2 percent grind breakage.

During this process of improvement, we validated all grind process changes with wafer strength measurements, and grind breakage trend analysis. We have a tool available which will measure the breaking strength by applying a force to the wafer until it breaks, and recording the force. Figure 5 below shows data we used to implement a stress relief etch. We also used this method to make decisions on grind factors such as wheel type (solid vs. slotted), feed rate, table rotation, spark out, tape type, and wheel vendor.

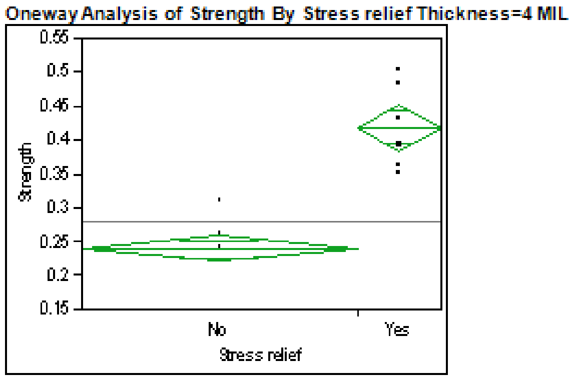

Figure 5: Wafer Strength ANOVA

RESULTS

Figure 6 below shows a timeline of yield vs. process changes that were introduced to the grind process. Using the data analysis system defined above, we are able to gauge the effect of process changes and react quickly to excursions that may occur. Fortunately, the grind breakage rate has been consistently low for a long time. We are currently running at about 0.2 percent breakage rate at grind for GaAs wafers 4mils – 8mils thick.

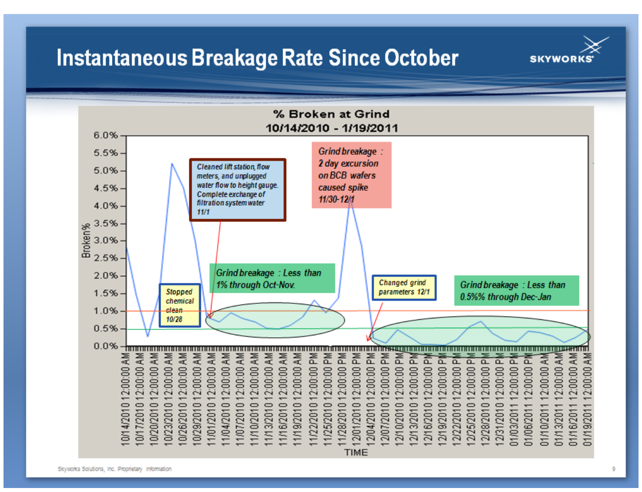

Figure 6: Effects of Process Changes on Breakage

As a result of our never-ending quest for perfect quality, Skyworks has been able to effect a 90 percent reduction in GaAs wafer breakage and to increase the line yield by 3 percent over the last two years. Figure 7 below tells a compelling story of the success of the team's efforts.

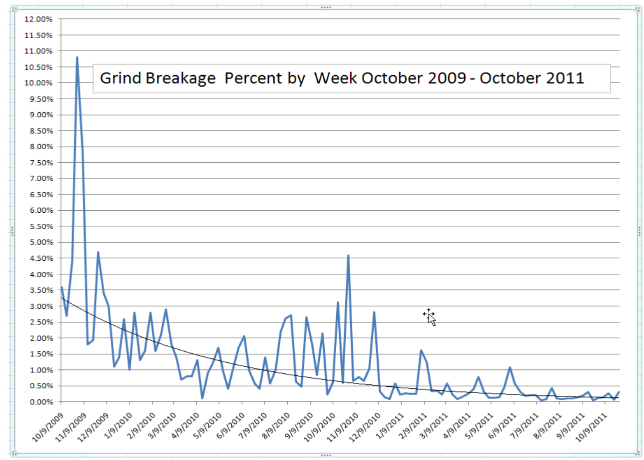

Figure 7: Skyworks Two Year Breakage Trend

We are not done yet; we are currently working on a new hard mount process that does not use any wax or thermal adhesive, but a selection of mounting tapes with or without a substrate. We started working on developing a process to mount wafers to a hard substrate (sapphire or glass), using tape products only. We had good results with that process, and are now moving a step beyond that and developing a tape only (no substrate) process. We have demonstrated at the pilot level that we can grind GaAs wafers to 4 mils with a tape-only process. We are looking forward to bringing this process to manufacturing. The reduced handling and cycle time from a UV expose/dismount vs. a thermal debond/solvent clean would improve breakage and throughput.

CONCLUSION

A sustained, data-driven approach to problem solving was used to reduce the grind breakage rate from the 4 percent range down to a predictable 0.2 percent. The improvement effort looked at all aspects of the process: facilities, equipment, materials, and process settings in order to reduce scrap.

ACKNOWLEDGEMENTS

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