

Yield Enhancement Using Final Outgoing Automated Inspection System

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ABSTRACT

Defectivity yield enhancement in GaAs manufacturing requires an accurate and repeatable process monitoring system. Manual inspections are not only unable to maintain both requirements, but also are more expensive over time. With that in mind CS-1 decided to implement an automated optical inspection system. Using the automated tool, the fab has been able to identify and resolve multiple defects caused by inline process variations, thus increasing and stabilizing the final yield. This paper explains the process of implementing this system and identifies both the difficulties and benefits involved.

INTRODUCTION

GaAs differs from silicon in requiring an end of line inspection system because all backend processing is completed in the fab instead of at an assembly site. These processes: thinning, source via, and saw, apply significant stresses to the wafers and can add many defects. The thinning process has the potential to introduce severe stress to the wafer that may result in fractures, and sawing GaAs has the potential to cause significant topside and backside chipping.

For the first several years of operation, the fab utilized a manual method of final outgoing inspection. This method required multiple production associates to use optical microscopy to inspect die samples from all outgoing wafers. This process was unreliable and became a factory bottleneck as die per wafer increased. Assembly sites regularly reported defect escapes and incorrect die quantities.

Another difficulty of manual inspection was the inability to accurately categorize defects. Because of these issues, it was decided to implement an end of line automated inspection system.

BENEFITS OF IMPLEMENTING AN AUTOMATED INSPECTION SYSTEM

Implementing the automated inspection system and process changes to address excursions, not only improved cycle time and reduced escapes, but also resulted in a significant increase in total FOI yield. As shown in Figure 1, initial implementation caused a reduction in total yield, but once all the systems were in place to catch defect excursions and prevent over rejection, the yield stabilized significantly higher than before implementing the automated inspection system.

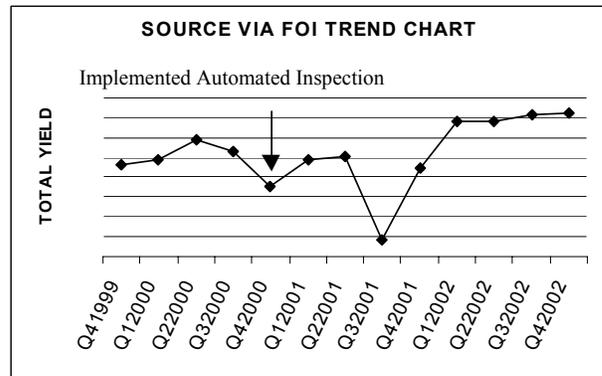


Figure 1: Total FOI Yield Trend Chart

Additionally, an automated inspection system gave the fab the ability to establish a procedure for full wafer shipment to assembly sites using automated wafermaps, therefore eliminating die handling and pick and place operations. In addition to improving the yield and escape rate, the automated inspection system improved cycletime by 66% and decreased labor cost by 75%.

TOOL DESCRIPTION

The automated inspection system was set up to import the unit probe maps and inspect only electrically good die, see figure 2.

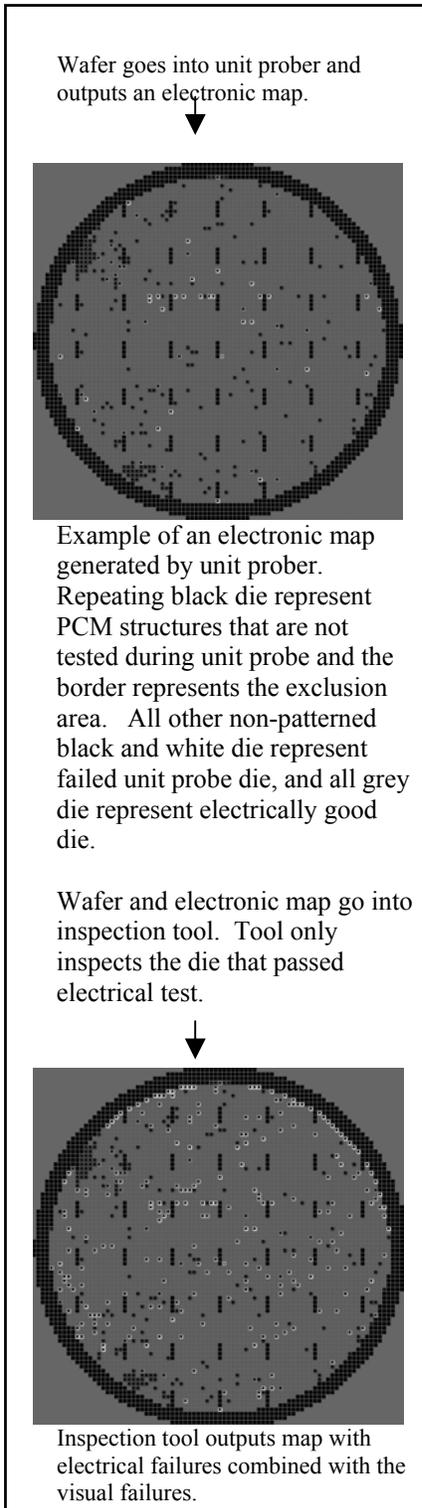


Figure 2: Electronic Map Process Flow

Once the map is imported into the inspection tool the die are then inspected for visual defects by using variations in reflected light. These

variations are identified by comparing a reference image to an inspected die. The user creates the reference image by training in many die that have been identified as good die. These die are stacked on top of each other to create a mean image and a standard deviation image. The mean image is the image used to compare the inspected die and the deviation image is used as the window of accepting or rejecting a variation in the reflected light of the inspected die. These variations in light are in the grey scale of 0-255, black-white respectively. If large variations of reflected grey scale light are trained into the reference image, then the tool requires an even larger grey scale difference in the defect for the tool to reject it. Therefore any significant process variations have the potential of causing escapes.

TOOL LIMITATIONS

The challenge in implementing an end of line automated optical inspection system lies in setting up a tool to accept variations in a die while rejecting true defects. Therefore sustaining the tool requires an important balance between minimizing over rejection and minimizing escapes. Due to process induced variations in the surface roughness of the gold features, there is a high risk of over rejection. Although rough gold passes defect specification, the system may reject die with rough gold if the tool was trained to another wafer in the lot that may have smooth gold. To prevent this, an out of control action plan was established. If an operator finds that die have been incorrectly rejected, they will retrain the reference image to include rough gold.

Another threat of over rejection with this system is posed by particles on top of the passivation. Because the tool uses a comparison system, reference image to inspected image, an accepted die must be clear of any debris for the tool to accept it. This includes particles or residue on top of the passivation layer. Since the defect criteria allows this type of anomaly to be accepted, the tool again has the potential for over rejection. To prevent excessive over rejection, exclusion boxes are placed over some inactive features of the die which prevent that area from being inspected.

Along with balancing the over rejection, the inspection tool is set up to prevent defect escapes. Escapes are defined as die not being

rejected that fail the inspection criteria. For this factory, GaAs inspection criteria is defined with similar standards as silicon wafers. To aid in the definitions, the FOI group created a photo book that explains the criteria and identifies defects that are specific to the process. Assembly sites implemented use of the same book for dispositioning escaped defects. Escapes are closely monitored with assembly site feedback and quarterly correlation studies. For the past two years, the factory has maintained an average escape rate of less than 2%.

DATA COLLECTION

Once the wafers complete the inspection process, the types of defects and their quantities need to be passed back to the appropriate process groups to prevent reoccurrence. A sample of the defects are manually inspected and categorized based on the total yield of the wafer. For example, if the wafer yields high, then only 25 defective die are inspected and categorized, but if it yields a few percentage points lower, then a minimum of 100 defective die are inspected by an operator and categorized. This data is collected from each wafer and a scale factor is used based on the number of total rejected die for that specific wafer to determine an estimate of the rejected die for each category. For example, suppose the following data was collected from one wafer:

Total die rejected = 500
 Total die categorized = 100
 Total die categorized under FM = 40

Then the following equation is used to determine an estimated total die rejected for FM based on the sample inspection:

$$\frac{\text{Total die categorized in FM} * \text{Total die categorized}}{\text{Total die rejected}}$$

OR

$$40 * (100/500) = 200$$

This method allows the data to be weighted when there is a defect that is causing a low yield hit but does not affect every wafer. Consider the case of a defect that causes a yield loss of ~30% but it only affects ¼ of the wafers. If only the categorized defects were evaluated, the data might not show the severity of the problem. Using this formula the ~30% will weight the data

and more readily show the severity of the yield loss.

DATA ANALYSIS

The yield data for all lots is tracked and presented each week in trend chart and pareto chart format to monitor any variations in the line. Multiple defects have been found using this system. A consistent defect, sapphire hole demount residue, increased significantly after a new cleaning process was implemented, see figure 3.

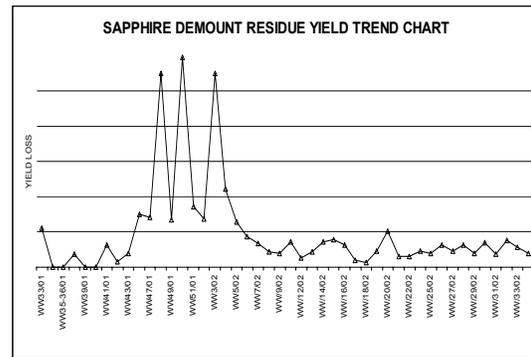


Figure 3: Increase in Sapphire Demount Residue Found at Beginning of 2002

Note the high peak found at the end of 2001 time frame. The first few lots with the new process did not show the increase. However, after the first week, the inspection and categorization system detected the rise in yield loss of the subsequent lots. Root cause was quickly identified.

This system also works for catching new defects. To aid in identifying new defects, all lots that yield below a specified amount go on hold for engineering to evaluate. Once engineering determines which defects are causing the low yield, the history of the lot is investigated. Each of these low yielding lots is tracked into a spreadsheet so that repetitive problems can be identified and investigated prior to completion of the weekly trend charts. Initial investigation includes lab analysis of defect, SEM, FIB and EDS, along with commonality studies of affected wafers or lots. This information is presented along with the trend charts. When a significant shift is identified, a processing team is established to investigate root cause.

An example of a new defect identified and resolved was a defect in plated gold features identified as the “Rose” defect, see figure 4.

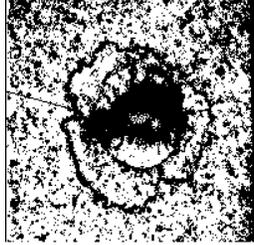


Figure 4: Rose Defect

The defect was quickly identified during the categorization of rejected die on the automated inspection tool. FIB analysis showed the layer that caused the defect and the lot commonality identified the individual tool used at the layer in question. The process engineer in charge of the tool quickly identified the root cause within a plating tool.

Many other defects are cyclic and require more intensive monitoring such as those caused by the saw process. Because wafers in any lot are processed across all saws, it is difficult to identify a specific tool that is causing a topside chipping problem. One reason it is difficult to monitor is that if only one or two wafers from each lot is processed through the saw tool that causes the chipping then the data will not be weighted enough to show a response. So to combat this, a feedback system was implemented to identify the location and type of saw defect on affected wafers. This information is monitored and provided to the saw process engineer. This system has provided a more timely and detailed response to saw process variations.

CONCLUSION

Fundamentally this automated inspection process requires consistent monitoring for it to be successful. Those that do the monitoring must be familiar with the standard process defects to be able to identify a shift or irregularity. Another important component is training all inspectors to categorize defects the same. And as defects change, the category list requires updating or further breakdown.

The benefits of implementing the automated inspection system and process changes to address excursions have resulted in a significant increase in total FOI yield. Improvements to this system include an inline automated inspection system. The inline system will compliment the FOI process to stabilize yield even more. Fewer lots will be affected during an unintentional process shift because an inline monitoring system will catch defect excursions sooner.

ACKNOWLEDGEMENTS

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ACRONYMS

GaAs: Gallium Arsenide
FOI: Final Outgoing Inspection
SEM: Scanning Electron Microscopy
FIB: Focused Ion Beam
EDS: Energy Dispersive Spectroscopy