Rework Reduction and Optimization of 150MM Wafer Mount Process

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Abstract:

In September of 2010 a project was initiated to reduce the rework rate and optimize the process at the wafer mount operation for 150mm acoustic wave wafers. A fishbone diagram was used to explore the variables in the process and determine the leading causes of high rework rates. This paper will discuss the steps taken to significantly reduce the mount rework rate and maintain an acceptable process.

INTRODUCTION:

The 150mm Silicon acoustic wave wafers at TriQuint are mounted to 152mm Silicon carriers for back grind. The mount process includes several cleaning steps, coating the wafers and carriers with a wax bonding agent, pressing the wafer stack together, and measuring the thickness uniformity of the mounted wafers. Additional measurement steps are also added in between the processing operations. See Figure 1 for a depiction of the process flow. To achieve significant improvements in process robustness and consistency, variables included in the 4M and 1E categories (man, method, machine, material and environment) were explored and evaluated.

EXPERIMENTAL:

A fishbone diagram was utilized to brainstorm likely sources of error in the process. 4M and 1E were each analyzed individually before any changes or improvements could be made. Each operation was investigated from several different points of view, with the compiled results described below for each section of the fishbone.

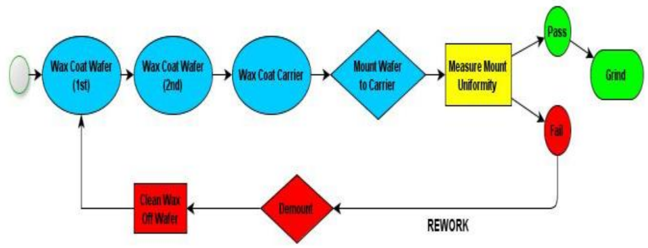

Figure 1 – Mount Process Flow Chart

Man

Human error is something that almost any process or experiment must account for. In this mount process, there were several opportunities for operators to introduce undesired variations into the process. Wafer handling by operators is one aspect that cannot be eliminated, but it certainly can be minimized and controlled. One significant change introduced to the process was the use of the automated flip arm to align wafers to carriers instead of manually centering and notch-aligning before mount. The flip arm on the mount tool had to be modified and adjusted by equipment engineers so that it could be used for multiple processes simultaneously without sacrificing the centering and alignment quality of any individual process. The previous process required operators to hand-align and center the wafer on top of the carriers, introducing an operator-to-operator variation in alignment quality. In addition, different operators would press the stack together at different pressures which could affect the uniformity of the mounted stack and lead to reworks.

Wafer handling was also significantly reduced by improving the coat and bake process by replacing the ex-situ cure on the mount tool after wax coat with an in-situ bake process on the coat track. This change will be described in more detail in the next section. In terms of human error, the change helped to eliminate handling wafers to bake them one at a time on the hotplates of the mount tool. Wafers were often chipped when aligning to the pins on the hotplate and could also be dropped during transport to and from the hotplate. There was also a great chance of over-baking because the operators had to use a stopwatch to track the bake time of each wafer. An optimized in-situ bake was placed to completely remove the ex-situ cure operation and decrease chances of human error that often led to reworks and/or scraps.

Method

When analyzing the possible causes for reworks and errors, the actual process itself must be investigated. As mentioned in the previous section, two major changes were made to the coat and mount process: flip arm usage and an in-situ bake after wax coat.

The flip arm was not originally used because the tool required frequent setup changes for different wafer sizes and types. A combined effort between equipment and process engineers resulted in the development of tool setup protocols that allowed the use of the flip arm which resulted in a reduction in reworks due to off-centered attachment of the wafer to the carrier. Once the centering and alignment were perfected, another issue that had to be optimized was the "gap" between the flip arm and the carrier on the hotplate. Since the flip arm transfers the wafer onto the carrier, the gap had to be set so that the wafer could settle onto the carrier without sliding out of position when released but would also not touch the carrier until release. This aided in reducing reworks due to alignment as well as reducing the risk of device structures being damaged. Multiple iterations of this parameter were tried before the gap was set to work simultaneously for several different wafer/carrier sizes, device types and substrates. Eventually, this task was achieved and has been maintained without any major issues.

The wax cure bake on the mount tool was replaced with an in-situ bake on the track used to coat the wax on the wafers and carriers. Potential issues of replacing the original process included under-baking and leaving too much solvent to flow out during or after mount, wax cracking due to thermal shock after baking, and harming the overall mount uniformity and increasing reworks even more. DOEs were run to evaluate optimal time, temperature, and cooling. A slow-cooling step on raised hoplate pins was added and the chill plate was bypassed to solve the cracking issues. This was critical because cracks can be detrimental to the bonding ability of the wax. Once the process was finalized, it was tested and verified on both pilot and production wafers to ensure that no physical or electrical defects were introduced.

Machine

Several tools play a key role in the quality and efficiency of the mount process. The wax coat track, the mount tool, and the thickness measurement tool were the focus for improvements in the "Machine" category.

Poor thickness uniformity of the mounted wafers is one source of rework, so the wax coat uniformity was considered first. Dozens of new recipes were tested, making sure to maintain the same thickness while trying to improve uniformity. Since the wafers are double-coated, the uniformity significantly decreases after the second coat. A radial dispense was used to coat the wafers, meaning that the dispense arm was moving while dispensing the wax onto the wafer. The recipe was improved to use better timings and spin parameters to eliminate any shark-teeth (see Figure 2) or other coating defects often seen after the second coat. Furthermore, a 40% wax reduction was made after noticing how much chemical was being spun off the wafer during coat, leading to additional cost savings.

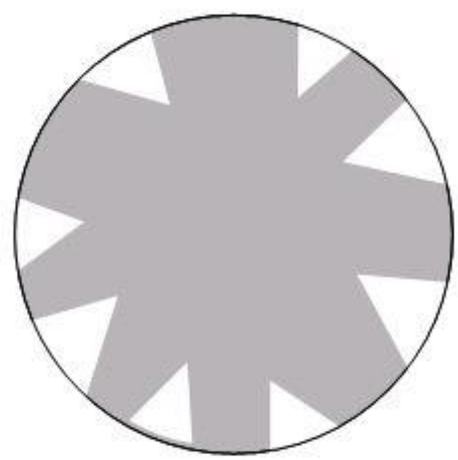

Figure 2 – Shark-Teeth Coating Defect

The mount tool was also analyzed and checked for any potential improvements. SensorProd pressure paper was utilized to determine the pressure that the "bladder" was applying to bond the wafers to the carriers. The paper turns different shades of pink to indicate the amount of pressure being applied at different spots on the wafer. The intensity of the color can be used to determine the actual pressure in psi units. This was used to help determine the uniformity of the bonding process and to verify that the ideal parameters were being used for the process. The pressure paper was also used to match and qualify a second bonding tool for the process.

Finally, the metrology tool used to measure wafer thickness was investigated to determine how accurate the readings actually were. A manual tool requiring the operator to move the gauge to different locations on the wafer is used to measure the wafers. The thickness data is automatically input into a software file that evaluates the mounted stack for wedge, dip, and bump. Upper limits for each category of non-uniformity are set, and if these are exceeded the wafer requires rework. Both the measurement tool and the analysis program were investigated. The 16-point measurement map is displayed in Figure 3. A gauge R&R study performed on the measurement tool showed that its repeatability and reproducibility were both below par. Operators could manipulate the readings simply by adjusting how hard they pushed down on the wafer. A non-contact automated metrology tool was put in place to replace the manual tool.

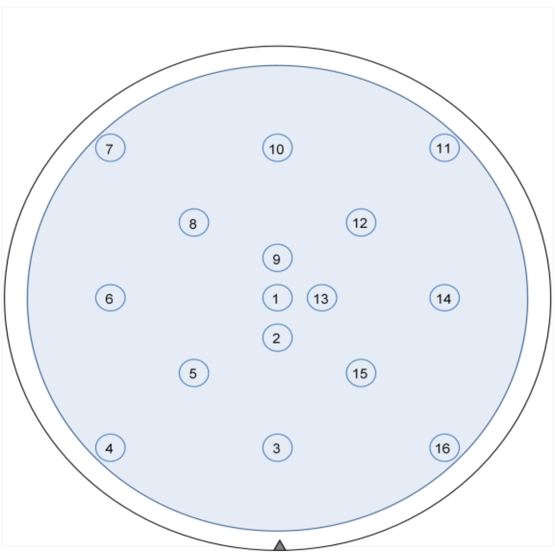

Figure 3 – Post-Mount Measurement Map

Material

The wax, product wafers coming into the process, and the carrier wafers were all looked at for sources of improvement. The wax was investigated while improving the coat process. The product and carrier wafers were both measured for thickness and uniformity. After measuring about 75 wafers of each, it was found that there was a noticeable deficiency in the uniformity of the carriers being used. In fact, when the thickness data was input into the pre-grind rework algorithm to check uniformity, nearly one third of the carriers had a failing uniformity! When adding a wax coat and a double-coated wafer on top of this non-uniform carrier, it is no surprise that the rework rate was very high. After this discovery, all carrier wafers were measured and evaluated, and all non-uniform carriers were discarded. Ultimately, a complete new batch of "ultra-flat" carriers was ordered to replace the previous supply.

Environment

The manufacturing environment was also investigated for any issues that may be negatively affecting the mount process. The clean room areas were inspected to verify that the proper supplies and resources were available for operators to perform optimally. One improvement that was made was the addition of cooling racks inside the mount tool as seen in Figure 4. This allows up to six wafers to be cooled inside the mount tool rather than hand-carrying each individual mounted wafer back to the table located across from the tool and placing it on clean room wipes. Not only did this reduce the risks from extraneous wafer handling, but it also relieved operators from handling hot wafers and risking injury.

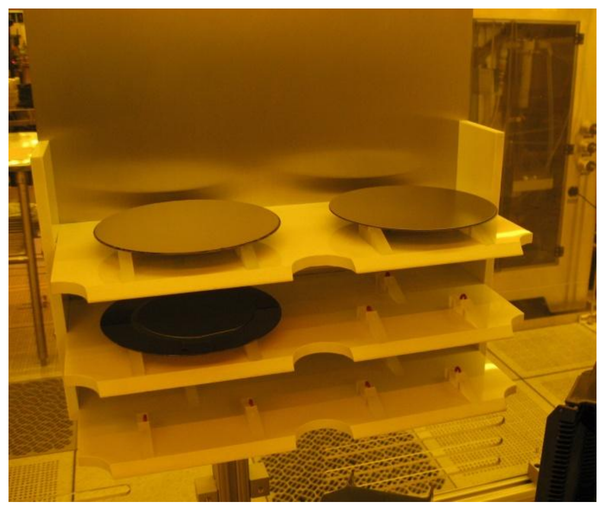
Figure 4 – Cooling Racks Inside Mount Tool

RESULTS:

Each change that was made to the process was thoroughly reviewed to make sure that it did not negatively impact the quality of the product wafers in any aspect, mainly the final probe and defects data. The data was presented to a technical review board (TRB) before any changes were implemented. The most significant improvement came from replacing the carrier wafers with new "ultra-flat" carriers. The rework rate drastically improved after the swap. This has been sustained by regularly measuring the carriers and discarding those that no longer meet the quality requirements. Process robustness and reliability were considerably improved due to each new modification. Figure 5 below shows the monthly mount rework trend for 150 mm acoustic wave wafers. The average remount rate between January 2010 and September 2010 was about 17.5%. The mount process improvement project began in September 2010 with a goal of reducing the rework rate to below 3%. Drastic improvements were seen just two months later. The average remount rate for 2011 was 0.86%. Not only did this save a great amount of manufacturing time, it saved the company hundreds of thousands of dollars per year in rework costs.

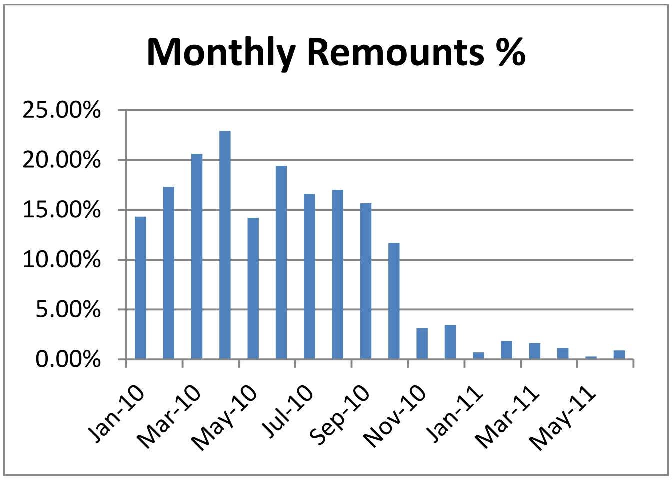

Figure 5 – Monthly Mount Reworks Trend

CONCLUSIONS:

Process improvements can lead to vast savings in time, money, defects, and other problems. They can be found everywhere and should not be ignored. It is often useful to use brainstorming tools such as fishbone diagrams in which all possible aspects of the process are analyzed for potential enhancement. Once each of these aspects are diligently explored and worked on, considerable changes can be made. As seen during the improvement for the acoustic wave mount process at TriQuint Semiconductor, the root cause(s) are not always obvious and predictable. Attacking all the possible issues with the process can help solve all process issues and establish an optimized and robust process.

ACKNOWLEDGEMENTS:

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REFERENCES:

ACRONYMS:

DOE: Design of Experiment