Lessons Learned from Laser Dicing

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Abstract

Every project has challenges that must be overcome in order to drive to completion. Bringing laser dicing up to production provided several lessons that will improve similar efforts at TriQuint and may be valuable to others within the industry. Issues to be discussed include 1) a surprising wire bond short caused by opening up a dielectric layer in the streets. 2) A late in the project change to the size of the hoop stretch rings needed for die separation. 3) Importance of die edge recast to die strength. 4) Low level die crack problem that occurred despite emphasizing testing for die cracks during the reliability testing (REL) portion of the project.

INTRODUCTION

After several rounds of testing at the manufacturer, TriQuint purchased DCM802 laser dicing tools from ALSI. The reduced kerf of a laser vs conventional saws provided a simple ROI based on an increase in die per wafer backed up by a 5X improvement in throughput over sawing. Based on the initial testing, the major risks/issues associated with this technology were identified as an increase in damage to dielectrics left in the street, a difference in the appearance of the diced edge of the die, potential for die cracks, effective removal of recast material, and the need to stretch the dicing tape in order to separate the die and prevent shipping damage. The attempts at understanding and compensating for these risks led to the issues that will be shared in detail below.

WIRE BOND SHORTS

The majority of TriQuint product lines leave some dielectric layers intact in the streets. Metal zippers surround each die, protecting them from any chipping of the dielectrics that occurs during dicing. In the early exploration into laser dicing, it was determined that the scratch protection Silicon Nitride (SiN) coating placed on the top of the die could be an issue. When this coating was left in the streets, it was possible for laser induced dielectric damage to move beyond the zipper and into the die. This was compensated for by removing just that top dielectric layer from the streets with the opening extending from center of zipper to center of zipper (see Figure 1). The opening was produced at the same time that the wire bond pads were opened so no new processing steps were required.

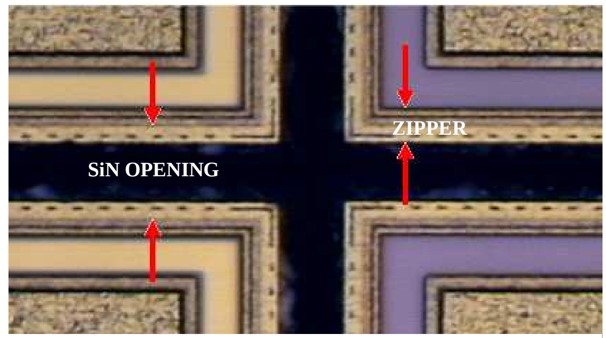

Figure 1. SiN Opening in Streets and on Part of Zippers

Initial testing of die with the new opening showed that it worked for preventing SiN chipping past the zippers. However, it uncovered an unanticipated issue at wire bond. One of our sub contract assemblers (SCA's) had a process that allowed the wires to sag when bonding chip to chip. The wire could sag to the point that it contacted the metal zipper and cause a short. While we had the scratch protect coating in place, it completely coated the metal, protecting it from wire sag. There was a two part resolution to this issue. First, the SCA fixed its wire bond sag problem (See Figure 2). Second, the opening in the SiN was reduced so that only SiN inside the street was removed, leaving the zippers completely covered plus 2um coverage into the street. Repeated testing showed that the reduced SiN opening provided the same level of protection from SiN chipping as the original opening that extended onto the zippers.

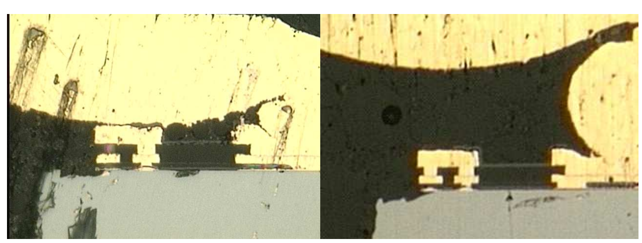

Figure 2. Cross Section of Bonded Wire Contacting Zipper (Left) and Sitting Above the Zipper (Right)

Hoop Ring Sizing

The large kerf from conventional sawing provided enough gap between finished die that there was no concern of die edges rubbing during shipment. The narrow kerf from laser dicing meant that completed wafers needed to be stretched on hoop rings (and removed from the original saw frame) in order to separate the diced die. The original process plan was to keep the wafers on the same sized saw frame independent of what style of dicing was to be used. This provided the minimum increase in capitol expenditure, but made for very tight working conditions when trying to fit a small hoop ring between the wafer and the saw frame (see Figure 3). Drawings and sample hoop rings were sent to three SCA's to verify that the small hoops did not cause them problems. All three had experience with wafers stretched on hoop rings already and gave the green light to proceed.

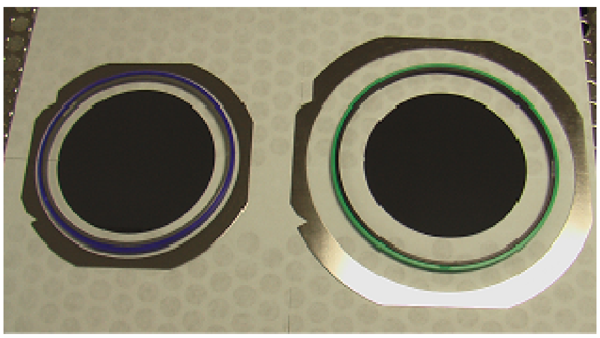

Figure 3. 6" wafers shown with original hoop and saw frame (Left) and current hoop and saw frame (Right)

It was a pleasant surprise to find that there were only minor issues with transferring diced wafers from the small saw frame to the small hoop ring. The recipe on the laser dicing tool required a minor adjustment to compensate for the small frame (due to tension of the tape from holding the frame down on the chuck) and the hoop stretching tool was more difficult to load with a small hoop, but it all worked – until the follow up batch of test wafers were sent to the SCA's to get picked.

The lesson learned from this experience is that complete samples need to be provided to the SCA's sooner. The drawings and sample rings were inadequate for discovering the die plate issues. Samples with wafers stretched on the hoop rings were sent as soon as a stretch tool (for putting the wafers on the hoop rings) was available on-site, but they could have been sent sooner if we had requested help from the vendor. It turned out that none of the SCA's had actually used small rings with 6" wafers. When the stretched wafers arrived, they all found that the small hoops prevented them from being able to pick all the way to the edge of each wafer. The end result was that we had to switch to a larger saw frame in order to accommodate a larger hoop ring, causing an increase in cost to the project as well as a delay. All of the tools for that part of the process had to be converted to a new saw frame size and a larger clean sink baths had to be ordered to accommodate the larger hoop rings.

Die Edge Recast vs Die Strength

The last two issues are related in that they involved a die crack event. This lesson will involve "how" it happened. The last lesson is focused on why it was not caught prior to turning on production. First, die cracking was identified as the largest risk to the project, but the original concern was the shape of the "cuts" in the die edge rather than the impact of recast (see Figure 4) on die edge strength. The original proposal for cleaning off recast material was to use a water soluble coating applied prior to laser dicing in order to remove recast from the top of the die, ignoring any recast on the die edges. When a post dice etch clean was explored as an alternative method for removing recast, the results were also initially focused primarily on top side cleaning.

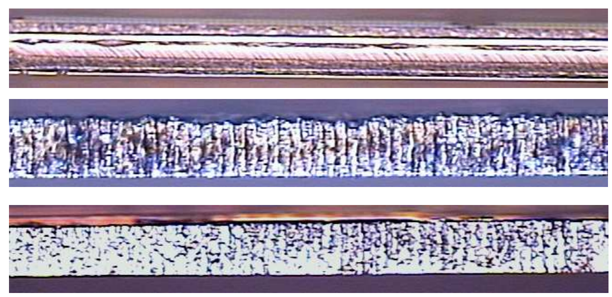

Figure 4. Die edge images typical for saw (top), laser diced with recast (center), laser diced after etch to remove recast (bottom)

Conversations with other ALSI customers who were laser dicing GaAs verified that they were performing a post laser-dice etch clean using similar chemistries as we had used in the past for a post-saw clean. The post-saw etch recipe was recreated and given minor adjustments in order to maximize cleanliness to the top of the die. Through the sharing of information from our industry colleagues and from ongoing work at ALSI, we learned that etch cleaning also made an improvement to die edge strength on laser diced GaAs die. Based on the similarity of the etch cleans and the end products (GaAs IC's), we moved forward with an etch clean in lieu of a top side protect coat clean.

Unfortunately, although the etch worked well to clean the top of the wafer, it did not completely remove recast on the sidewalls and did not provide a significant improvement to die strength for our die. This led to a die crack event that put a temporary stop to laser dicing until it could be resolved. The critical lesson here is that we may have avoided the die crack issue if we had reproduced the die strength testing with our own parts. We had viewed the etch clean more as an opportunity to avoid dealing with a protect coat process rather than a critical change for avoiding weak die edges.

Die strength testing (performed for us by ALSI) showed that although the etch was cleaning the wafer surface, it was not providing an effective benefit to die edge strength. Some of the reduced effectiveness may be from dicing along a different crystallographic orientation than the die used by ALSI in the original experiment, but much of it was simply due to differences in the equipment and setup of the etch clean tools and that we were not stretching the wafers on hoop rings prior to the clean. A more automated tool was purchased and the etch clean chemistry was changed to provide both a clean top side and clean die edge. Stretching the wafers on hoop rings prior to the etch clean also improved the effectiveness of the clean by allowing more room for the solvent to get between the die. These adjustments resulted in a die edge strength superior to our conventional saw process (see Figure 5) and elimination of the die crack issue.

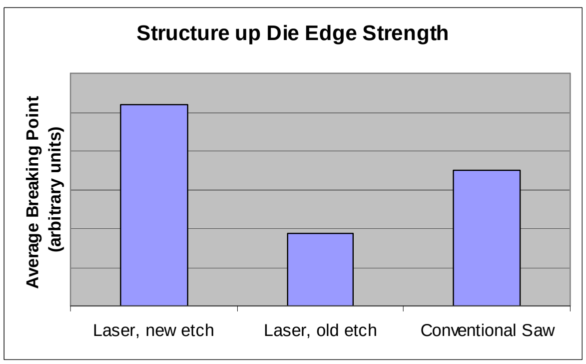

Figure 5. Impact of post laser dice etch on die edge strength

DIE CRACK ISSUE

REL testing was modified slightly for this project to provide additional crack detection capability. Multiple packaged products were tested, covering both module and stand alone parts. Also, temperature variations in temp cycling testing were increased in order to stress the die more than normal to propagate any micro-cracks that formed during processing. All REL testing was positive and no issues with die cracks were observed.

In all fairness, the low level of the die crack issue that did crop up (around a ½ % failure rate on 1 module part) may have escaped detection in any case. However, due to the way the package builds were chosen, even a large die crack problem would have been missed. This is because only one SCA was used for each build, but the SCA's had slightly different packaging methods. When the die cracking event occurred, it was limited to a single SCA – one not used in the qualification process. Subsequent investigation found that the SCA placed a higher stress on the die during packaging, which combined with the weaker die strength to allow cracking to occur.

The procedure used by the SCA was modified to reduce stress and to bring it in line with the process used at the assembly house without the issue. This was done in addition to improving the etch clean which subsequently improving the die edge strength. Also, a screen was created to detect and remove bad modules that had already been built. Re-qualification of laser dicing with the improved etch clean was done with splits across the SCA's, included thousands of additional die screened just for die cracks, and included a DOE that pushed the stress levels during assembly back up to the values that added to the die crack problem initially. No die crack fails occurred during re-qualification.

CONCLUSIONS

Although many parts of the laser dicing project went smoothly, the parts that did not provided important lessons that may help with future efforts. The impact of SCA packaging methods and the small differences from one assembly house to another were not fully appreciated or planned for. A much closer relationship between back end processing, the packaging engineers, and the SCA's has developed as a result of this project. The internal change control procedures now require more extensive splits at the SCA's for changes that may interact with their procedures. Engineering is now requiring material get processed and returned rather than just requesting feedback when testing new material at an SCA. Finally, we have learned new tools for testing die edge strength so that future efforts can be accomplished while maintaining die integrity.

ACKNOWLEDGMENTS

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ACRONYMS

SiN: Silicon Nitride
SCA: Sub-Contract Assembler
ALSI: Advanced Laser Separation International