Combining Vision Inspection and Bare Die Packaging for High Volume Manufacturing

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Abstract

A vision inspection approach is introduced for 100% die frontside and backside inspection to ensure quality control of our CuFlip™ bare die packaging process. Data from this inspection shows the accuracy and capability of our defect inspection, which plays an important role in process yield improvement and defect reduction.

INTRODUCTION

To ensure "zero defects" quality, multi-point inspections are required from wafer start to final die ship. Although current die surface inspection technologies such as 2D or 3D AOI and laser-based measurement [1] could effectively detect die/wafer surface contamination, photoresist residue, and bump topography, those inspections are typically done at wafer level prior to grinding and saw.

The challenges arise at die level after saw. Since die could be shifted and rotated during wafer tape expansion, complex calculation algorithms must be used to determine die position. Also, due to the wavy feature of wafer tape, 100% automated inspection is extremely difficult. Moreover, it is almost impossible to inspect defects such as chipping and cracking originating from the backside of the die, which could potentially lead to device failure.

In this paper, we will discuss an in-situ defect inspection approach in CuFlip™ bare die packaging. Two major inspections include die front surface inspection before the die is ejected from wafer tape and die backside inspection prior to packaging. Since the vision inspections are performed simultaneously with die pick & place, the cost of this operation is minimal and cycle time is not affected.

DISCUSSION

Pattern matching of four corners of the die in addition to die edges and saw street are used to locate the die position accurately. Die position determination is the first and most important step for the subsequent defect inspections, especially for die which rotated during the tape expansion process. Since the wafer tape expansion is not perfectly radial, die at different area of the wafer will have different rotation angles. Figure 1 shows rotation angles of die across the entire wafer. The measurement was taken from opposite the notch towards the notch, which is located at 6 o'clock. The data shows that die located at the top and bottom portion of the wafer are more disturbed through the wafer tape expansion with relatively large variation of rotation angles. Depending on die size, the rotation angle varies within one degree. This rotation angle will be applied and die images will be automatically corrected to match the rotation of reference die. Then the corrected die image will be compared to the reference die for defect inspection.

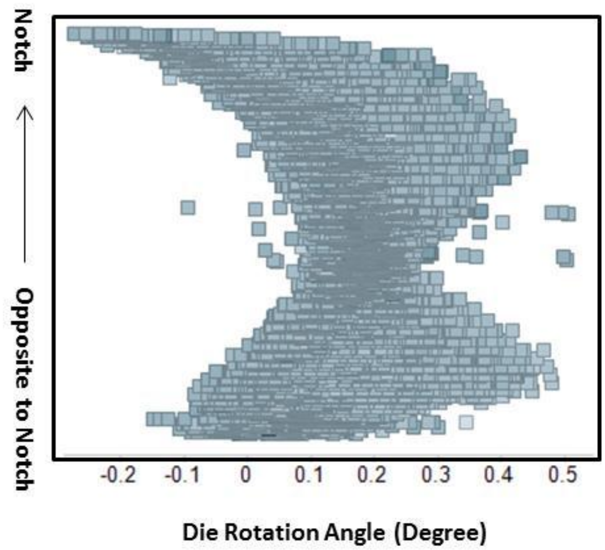

Figure 1: Rotation angles of die across wafer

For both frontside and backside inspections, die structure patterns extracted from a reference die image are used to determine the pass or fail of the inspected die.

DIE FRONTSIDE INSPECTION

A vision program is configured to inspect the die frontside before each die is picked from wafer tape. Multiple images of different light settings are obtained for the inspected die as shown in Figure 2. Then patterns

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extracted from those images will be compared with pre-taught reference images. Figure 2 (a) shows a bright field image of a sample die. The die edges, surface features, and protective guard ring show very well in the field of view. This bright field image can be used for die position determination, die size measurement, surface contamination, and chipping inspections. Figure 2(b) is a dark field image and shows that the dark field lighting provides uniform illumination on the bumps. This image can be used for bump position, bump size, and bump quality measurements.

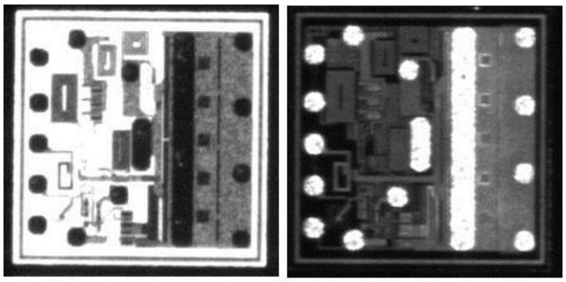

Figure 2: GaAs die images with different light settings

Figure 3 shows examples of frontside defects. Surface contamination, scratches and particles, as shown in Figure 3 (a), can be detected using the bright field image. In this inspection, bump area is excluded so that measurement of small particles and small area surface contamination is more accurate. Particle length and contamination areas as small as 10 µm and 25 µm^2 respectively can be detected by the system.

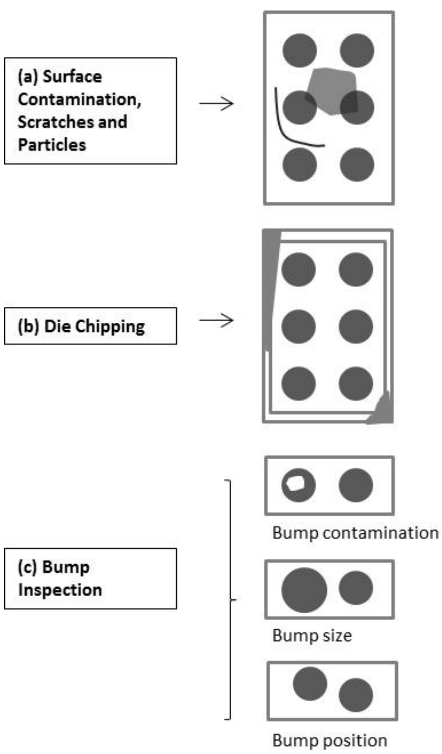

Figure 3: Examples of frontside defects

Two methods are used to detect frontside edge chipping. As shown in Figure 3 (b), for die with protective guard rings if any chipping crosses the guard ring that die is classified as defective. This is typically used for CMOS die and mechanically sawn GaAs die. For laser-sawn GaAs die [2], chipping depth greater than 10 µm from the die edge is considered a chipping defect.

For bumped die, both bright field and dark field inspections are configured to detect bump contamination, bump size variation, and bump positions, as shown in Figure 3 (c). First, bump position is determined and compared with the reference die. The top image in Figure 4 shows a histogram of bump position relative to the position on the reference die.

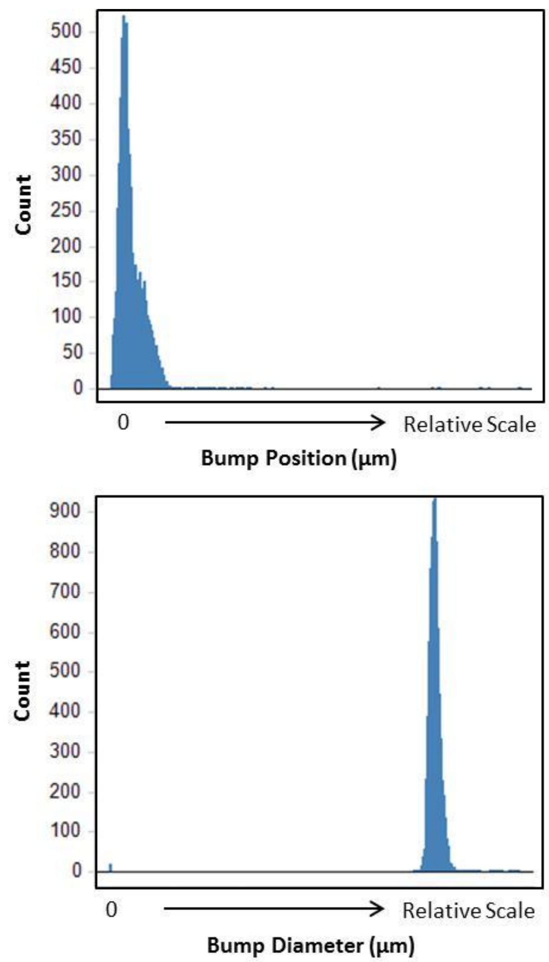

Figure 4: Histogram bump position and diameter

Bump position with an offset greater than 10 µm compared to the reference die is considered defective. Bump diameter is calculated for each bump. The bottom image in Figure 4 shows a histogram of the diameter of one bump. A bump diameter of "0" indicates a missing bump which renders the die defective. Bumps that are too small or too large can be accurately detected and defined as defectives if bump diameter differs from the median value by more than ± 20%.

DIE BACKSIDE INSPECTION

The die Backside is inspected after the die is ejected from wafer tape. Defects such as backside edge chipping, corner cracks, and backside contamination can be effectively detected during backside inspection. Coaxial light is used to get the best image of the die.

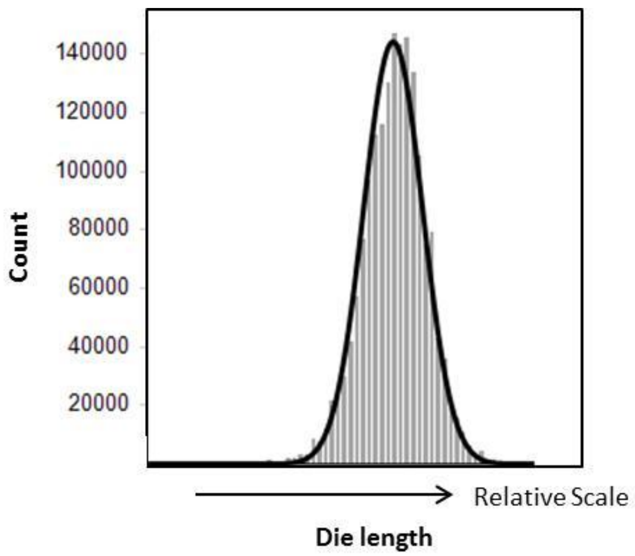

Figure 5: Histogram die length measured on backside

As is done in frontside inspection, the rotation of the die is determined and also the die size. Figure 5 shows an example of the distribution of the die length with a Gaussian distribution fitted (black line). Die too large or too small indicate a saw or die crack problem and are therefore screened out.

Die backside chipping is defined by the chipping length from the edge of the die. For different materials, the defect chipping lengths are defined differently according to their crystalline structures and breakage planes.

In addition, we developed a unique four-pattern matching procedure for backside inspection. As shown in Figure 6, the top and bottom patterns are used to detect any corner crack. With this inspection, corner crack area as small as 30 μm^2 can be detected. This high accuracy is extremely important for small size die that are laser diced.

The other two patterns are to determine edge chipping and backside contamination/crack. For each defined die pattern, high quality matching is used for backside inspection to ensure 100% defect detection. Figure 7 shows examples of backside defects inspected using the four-pattern matching procedure. One advantage of high quality pattern matching is that even though an individual defect could pass the previous inspection if the defect criteria are not met, it will still fail the pattern matching. For example, even if the chipping length (from the edge) is within or on the edge of the defect limit criteria as shown in Figure 7 (a), it still fails at pattern matching inspection due to large defect area.

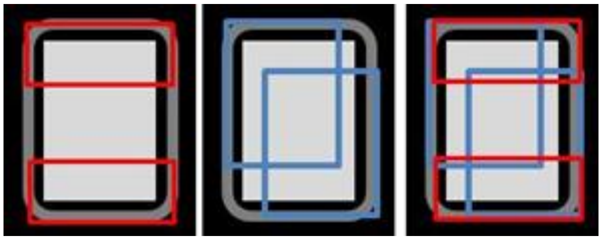

Figure 6: Schematic plot showing four-pattern matching

Figure 7 (b) shows a cracked die detected through backside inspection. Die cracking could be caused during Fab processing or in the die packaging process. The capability of cracked die detection during bare die packaging plays a very important role in preventing major quality excursions. Die cracks originating from the backside of the die can be detected and investigated at the earliest packaging step, which prevents further scrap and ensures high assembly yield. More importantly, backside inspection allows only good parts to be sent to our customers. Figure 7(c) shows backside contamination detected using the four-pattern matching inspection. Backside contamination/damage could act as a stress concentrator in the subsequent packaging thermal tests. The ability to do backside defect inspection is a big advantage, especially for thin die packaging that is sensitive to mechanical stress.

Backside inspection data also provides useful information for upstream process improvement. Backside chipping, die crack, and die size data has been fed back to Fab Operations for process improvement. Several defect reduction projects that resulted in quality and yield improvement have been executed based on backside inspection data.

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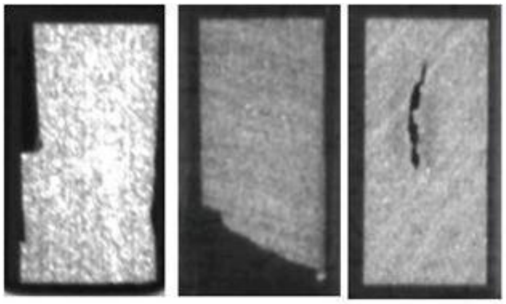

Figure 7: Examples of backside defects

High accuracy backside chipping and die crack inspections are very important for new process and product qualification. In modern semiconductor technology, the drive for reducing package size leads to the trend of smaller and thinner die. In the past few years, a laser sawing process has been established at TriQuint for thinner GaAs wafers [2]. All laser-sawn products have been closely monitored by our highly efficient backside inspection. With the continuous drive for ultra-small/thin die, backside inspection of high volume die packaging will play an essential role for the success of new process/product qualification.

CONCLUSIONS

100% bare die frontside and backside inspection are important steps toward zero defects. Those operations ensure that only good parts will be packaged. In addition, defect data collected through these inspection procedures is very valuable in analyzing root causes of various defects.

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REFERENCES

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[2] Travis A Abshere, Moreen Minkoff, and Bill Howell, *Lessons Learned from Laser Dicing*, 2008 CS MANTECH Technical Digest, pp. 69-71, April 2008.

ACRONYMS

AOI: Automated Optical Inspection