Advanced Low-k Die Singulation Defect Inspection and Pre-emptive Singulation Defect Detection

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Abstract

Advanced packaging has a challenge on its hands in dealing with reliability issues caused during singulation. Specifically, in the case of Wafer Level Chip Scale packaging (WLCSP) where the sawn die edge is the package edge and is exposed. WLCSP manufactured on the newer nodes are based on Ultra-low K dielectric material. This material is inherently porous and mechanically fragile. During the singulation step, there is a likelihood of creating chipping and delamination. Rudolph have developed a comprehensive approach to detecting defects generated at the laser grooving and saw process steps. There are two recommended approaches. The first approach is an inspection approach that is focused on detecting the defects after it has occurred. The second, a more sophisticated approach is to attempt to pre-empt occurrence of defects. In the first approach– die seal ring inspection, algorithms have been developed around the die seal ring to ensure the die integrity. These algorithms not only include the capability to detect the defect but also measure the defect size, defect position and frequency of defects. All of this is done while minimizing false defects that are typically found due to street and reticle artifacts that are often falsely detected as chipping. This enables customers to perform advanced disposition to ensure the optimal balance between shipping good die and preventing the shipment of potential reliability fails.

The second approach – Kerf metrology and Saw control comprises of Fault detection and classification (FDC) to record equipment data during the singulation processes and inspection equipment to detect surface defects such as chips, delamination and cracks. The combination of FDC to monitor equipment performance and the ability to correlate Metrology/Inspection performance data enables customers to not only detect defects but preemptively eliminate them. Poorly singulated dies can now be analyzed all the way back to the process equipment signals. Once these signals are identified they can be monitored to prevent or alert operators of possible excursions. These analytics will help customers define and ramp robust processes, justify consumable costs and ultimately lead to a better understanding of this difficult and challenging process. Finally, specific YMS capabilities exist to align and analyze the collected equipment and process data.

1. Die Seal Ring Inspection

Traditionally the inspection of post-saw defects was to inspect the active die area. An attempt is made to get as close to the edge of the die as possible. Any intrusion into this area is considered a defect. If the street area is included in this type of inspection, then there are even more false defects generated as street information may not be repetetive. Inspection systems typically use a reference image to compare the defective die image against a known good image at the same position. This works well for within the die when the die images are 100% repeatable from 1 die to another. When inspecting outside of the dies, there are often many artifacts that are not repeating from die to die, such as parametric test patterns and litho alignment features that under normal inspection algorithms will cause false defect detection. The figure shows a reference image which is die based versus a new reticle based approach.

Fig 1.0 – Single die (Left) vs Reticle Approach (Right)

In the case of the single die reference image, one reference model used for all die. Sensitivity is greatly reduced in street regions and the data will be corrupted by false detection. Complicated binning strategies are required to reduce nuisance defect count in the streets.

In the case of using a reticle based reference reference model created for each die within the reticle. The street area is inspected in the same manner as active die area. Simple binning strategy can be utilized for ROI placed outside seal ring region

1.1 Die Seal Ring Inspection Results

A typical inspection criteria on post-saw looks like the following table
For high-speed inspection TSW2 or depth measurement in Z is impractical. It may be possible with additional metrology options. The following Inspection study focussed on detecting D, E and CT regions.

The Regions of Interest (ROI) were set up in the following manner to correspond to the inspection criteria (Fig. 1.2): 

The results of the inspection were the following: 

Note the distribution of defects in the histogram on the top left corner that breaks the defects down by inspection criteria. The histogram is reproduced below (Fig. 1.4):

Compared to the standard wafer inspection the die seal-ring inspection produced the following results (Fig. 1.5):

The key column in Fig. 1.6 is the nuisance defect reduction. With the Die-seal Ring Inspection turned on, one can see a dramatic drop in nuisance defects, while detecting all the critical defects such as the Seal ring contamination with more accurate binning.
In conclusion, for post-saw inspection to detect chipping and post-saw defects, die-seal ring inspection can help improve Inspection yield, reduce review due to fall-out, reduce escapes and enhanced capture rate of the critical saw defects.

2. Kerf Metrology and saw control
Rudolph has also developed a sophisticated pre-emptive approach to delamination and chipping control. Through a combination of Kerf metrology and Fault detection and classification (Fig. 2.1), conditions in equipment that cause chipping and delamination may be detected and pre-empted resulting in significant savings in scrap.

Kerf metrology capability allows for high speed measurement of the following criteria (Fig. 2.2)

Rudolph’s KERF solutions enables considerable cost savings through implementation of Advanced Process Control (APC) techniques. It allows for identification of problematic regions with chipping/delamination. Suspect dies can be binned via flexible strategies resulting in a reduction of Field returns. Production robust recipe development can be implemented within hours, not months. One can fine tune SAW recipes to improve production yields and higher uptime. In addition, Inspection and Metrology recipes can be verified production ready faster. The benefits are direct Yield improvements. Reticle repeater and systematic chipping issues can be easily identified. There are benefits to equipment maintainence costs, tool to tool monitoring and process improvements. It is easier to monitor consumables such as blade usage and consumption via dedicated charts and reporting specific to the Saw process.

Fig. 2.1 – Post Saw Inspection Solution

Fig. 2.2 – Sample process measurements

Typical measurement generated looks like Fig.2.3 & 2.4

Fig 2.3 – Clearly see chipping performance difference by Blade edge

Fig. 2.4 – Metrology showing chip results by blade edge
In parallel with the metrology taking place on the Inspection tool, detailed saw equipment parameters are monitored and fed to Equipment Sentinel FDC software (Fig 2.5). The data can also be generated to provide a wafer level view of the details of each measurement criteria.

As shown in Fig 2.6 the results of the FDC trace signals and the metrology can be overlayed to show the process changes based on SAW recipe improvements. This gives process engineers insight into which process signals they can tweak in order to reduce the defects such as chipping.

**Fig 2.5 – Multiple Equipment sensors are monitored in real time**

**Fig 2.6 – FDC / Metrology Correlation Chart**

4. Conclusions

We have presented two approaches to managing process defects from singulation. One an inspection only approach that can be an effective gate to detect chipping and delamination and yet minimize review and false defects. The second is a closed loop kerf metrology and FDC based process control approach. In the second approach it is possible to proactively monitor the tool conditions that would lead to chipping and delamination and optimize the recipes to reduce the occurrence. We welcome discussions with Rudolph as to how we could help you solve this important industry problem.

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