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Assembly Wirebond Process Solution for Mitigating Leadframe Bouncing on Multi-Die QFN Device

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Modification and improvement of an existing tooling design in semiconductor packaging industry has been a usual practice, to enhance the current setup and to provide a solution to a specific assembly problem. This paper discusses the solution in eliminating the smashed ball defect occurrence observed after wirebond process. Smashed ball is usually encountered if the unit is unstable and creates a bouncing effect during wirebond process. It is therefore important to mitigate this micro-bouncing effect by analyzing the package design and the window clamp and top plate (WCTP). The objective is to increase the stability of the unit during wirebonding, especially for quad-flat no-leads (QFN) package with no tape. To achieve this, the solution is to alter the vacuum hole design of the top plate from single hole per unit to multiple holes of varied sizes per unit. Ultimately, after changing the design of the top plate, the micro-bouncing encountered during wirebond process was significantly reduced. This in turn created a consistent ball formation in all bonded wires. The comparative data presented in this paper confirmed the effectivity of the redesigned WCTP. For future works and studies, the improvement and learnings could be used on devices with comparable configuration.

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1. INTRODUCTION

Semiconductor products composed of thinner and smaller packages inside an integrated circuit (IC) have experienced rising demand in the semiconductor market. New technologies like in quad-flat no-leads (QFN) platform have faced manufacturability issues, and one of the assembly processes mostly affected is the wirebond process. Wirebond process is a critical and important assembly process in semiconductor industry. It is responsible for attaching the wires through combination of heat, pressure and thermosonic energy, providing electrical connections between the Silicon die and the package leads or terminals. With new and continuous technology trends and state-of-the-art platforms, challenges are inevitable [1-5].

As large QFN packages are getting more complex, and configurations wherein two parallel Silicon dies are attached on the same unit are becoming common, the challenge to provide a stable unit during wirebond process arises. This is where the importance of having a good design of the window clamp and top plate (WCTP) comes into play. The purpose of the WCTP is to clamp and hold the unit during wirebond process. The window clamp presses on the unit, and the top plate has vacuum holes which pulls the leadframe into place and avoid unnecessary movements. The standard configuration of a WCTP is to have the vacuum hole in the center of the die paddle for a balanced distribution of vacuum force.

In an ideal state, if the unit is secured and properly clamped during wirebond process, a uniform ball formation can be achieved. Otherwise, this could induce bouncing during wirebonding which can result to smashed ball. To correct this, one approach is to increase the vacuum hole size of the top plate, to give more surface area where vacuum is applied. However, too large vacuum hole also has its negative effect because it can also cause bouncing effect if the bonded wires are placed on top of the vacuum hole. The key point discussed in this paper is to strategically place the vacuum holes on critical areas that need support to prevent micro-bouncing. To measure the effectivity of the new design, several process control methods are performed as required in the corporate specifications and work instructions [6-7], such as measurement of ball size, ball height, ball shear, wire pull, and intermetallic coverage (IMC) and ensured that these are above the product requirement to guarantee the quality of the product. Fig. 1 shows the QFN leadframe package design outline of the device in focus.

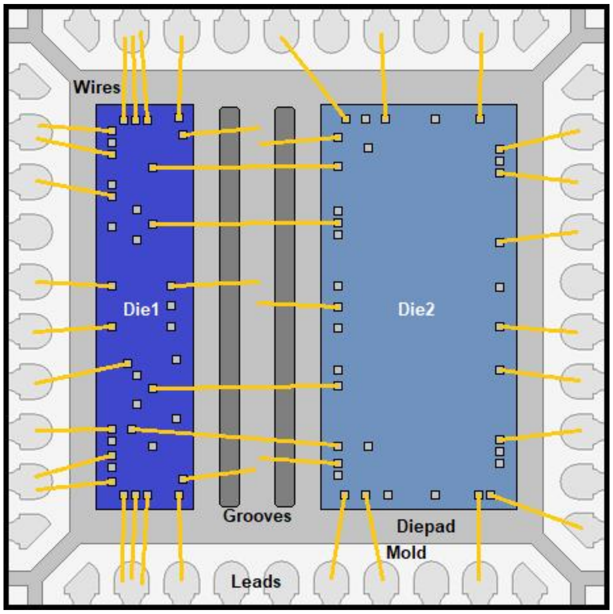

Fig. 1. QFN package design diagram

2. METHODS AND RESULTS

A typical assembly process flow for the QFN device in focus process starting from wafer preparation to singulation process is shown in Fig. 2. Highlighted is the focused process where the issue was encountered.

Smashed ball defect was the top major assembly reject in wirebond process for the device in focus, and this was seen during the development stage of the device. This smash ball reject is caused by a single-hole design of WCTP in Fig. 3 that cannot totally pull on the leadframe die paddle which corelates to micro-bouncing during wirebonding on Die1, and results to localized smashed ball at the upper and lower side of the Silicon die during wirebonding on the first bond. Actual reject unit is shown in Fig. 4. Parameter optimization was also done to address this problem, but still the reject manifestation occurred. Another drawback of this new technology is the requirement of 100% visual inspection after wirebond to screen-out the smashed ball seen.

The new design with multiple holes of varied sizes according to critical areas ensures that the unit is secured and properly clamped during wirebonding. The idea is to provide the critical location of the holes depending on the configuration of the device. Some works and studies on the WCTP design are shared in [8-10] to address the issues related to diebond and wirebond processes. The strategic location of the vacuum holes guarantees a well-balanced distribution of vacuum force and that the critical areas are also covered. With the improved WCTP design for large QFN package as shown in Fig. 5, the smashed ball occurrence was eliminated. The strategic location of vacuum holes provided a stable unit during wirebond process achieving a uniform ball formation on all bonded wires. Actual ball formation shown in Fig. 6 highlights the good ball formation after using the new WCTP.

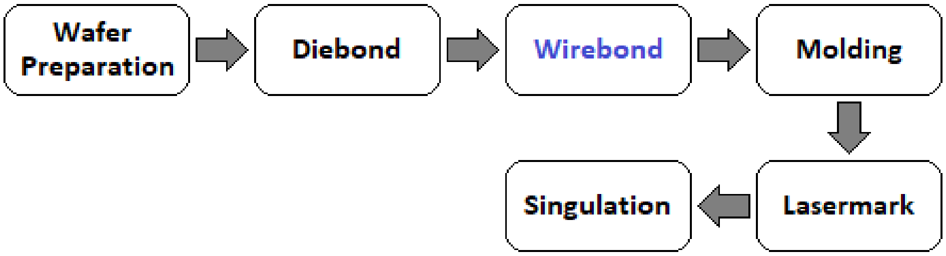

Fig. 2. Assembly process flow

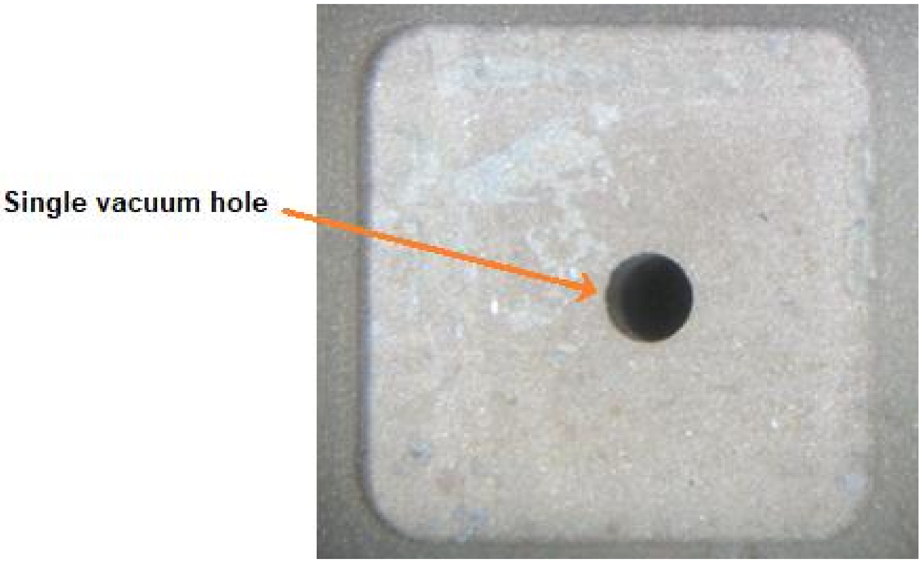

Fig. 3. Single-hole WCTP

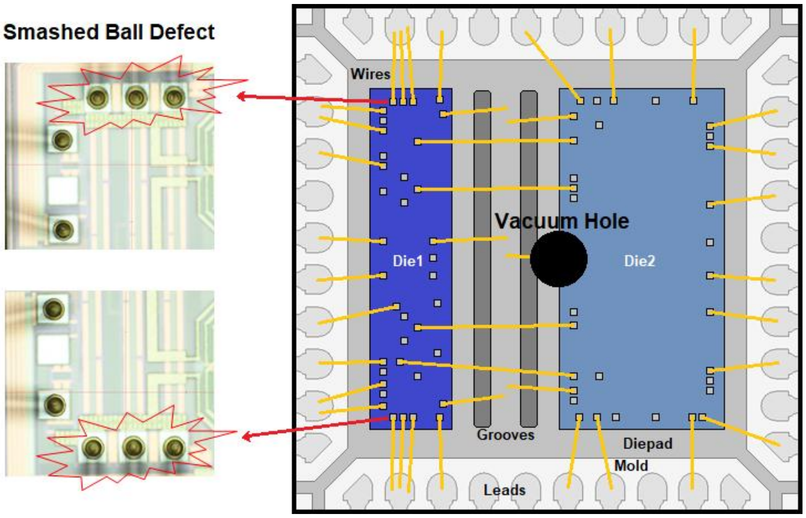

Fig. 4. Smashed ball defect occurrence when using single-hole WCTP

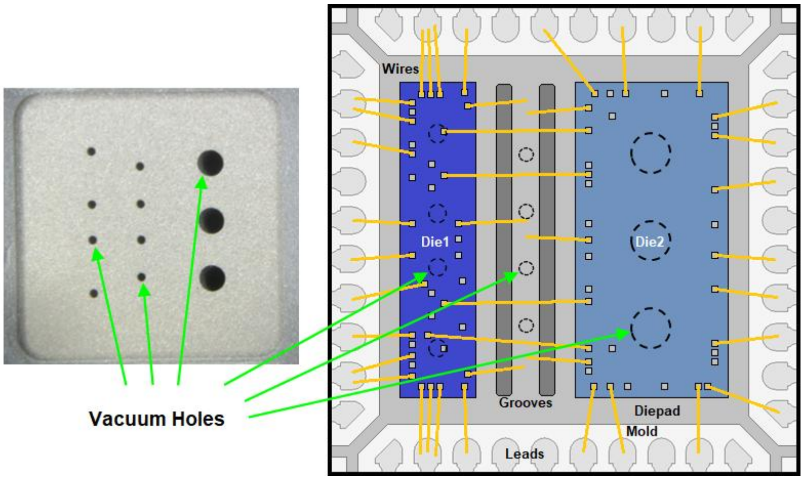

Fig. 5. Improved WCTP design with varied-hole configuration

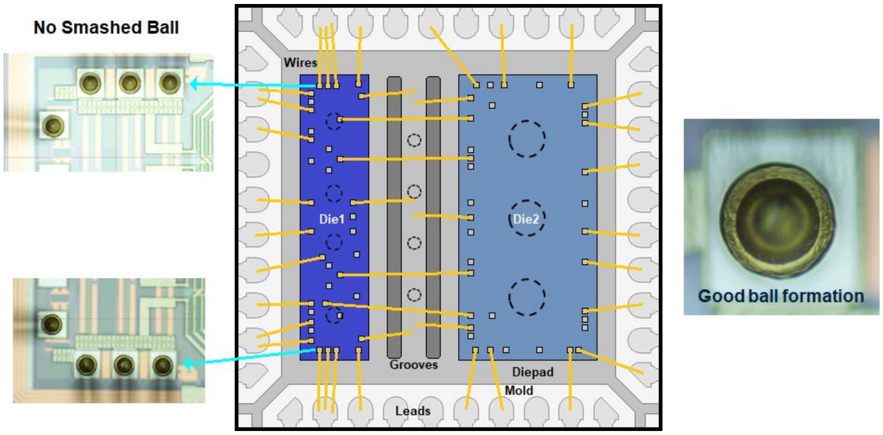

Fig. 6. Good ball formation when using the new WCTP design

Table 1. Wirebond buy-off response

Wirebond Buy-off	Ball Size	Ball Height	Ball Shear	Wire Pull	IMC
Minimum	54.30 µm	12.30 µm	23.90 g	13.27 g	84 %
Maximum	55.30 µm	13.10 µm	29.38 g	16.23 g	93 %
Average	54.80 µm	12.77 µm	27.14 g	14.61 g	89 %
Requirement	43.6 - 65 µm	7.2 - 20.1 µm	≥ 14.1 g	≥ 3.5 g	≥ 70 %
Remarks	Pass	Pass	Pass	Pass	Pass

Table 2. Ball shear test comparison

Ball Shear Test Comparison	Previous WCTP	New WCTP
Minimum	17.93	23.90
Maximum	25.96	29.38
Average	20.66	27.14
Standard Deviation	1.878	1.57
Ppk	1.165	2.77
Remarks	Fail	Pass

Aside from good ball formation observed after visual inspection, wirebond buy-off data in Table 1 shows that the target responses are above the product requirements. After data gathering, ball size, ball height, ball shear, wire pull, and IMC data showed passing results. Comparative data for ball shear test in Table 2 also shows significant improvement with the use of the new WCTP design. This is an indicator that the force applied on bonded wires are more even. The reduction in standard deviation on ball shear readings correlates to higher process performance (Ppk).

3. CONCLUSION

The improvement on the design of the WCTP is proven to be successful in resolving the smashed ball issue encountered during the development stage. This is supported by the data gathered after implementing the new design. After checking the critical wirebond responses and visual checking of ball formation, it was concluded that the new WCTP design is an effective solution without compromising the product quality. Also, after proving the effectivity of the new WCTP design, the 100 % visual inspection after wirebond process that was put in place to capture and prevent any escapees is no longer needed and can be returned to normal visual inspection procedure. The improvement on the WCTP design also provided a significant impact on the yield and has been valuable for a successful product qualification.

4. RECOMMENDATIONS

Learnings from this package should be applied and fanned out to other existing and future products with similar configuration. Worthy to note that continuous process and design improvement is vital to sustain the high-quality performance of semiconductor products and the assembly manufacturing. Works and studies discussed in [10-12] are useful in reinforcing robustness and optimization of the product during wirebond process. For future works, it is necessary to support the findings statistically for added analysis.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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