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Saw Singulation Characterization on High Profile Multi Chip Module Packages with Thick Leadframe

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Abstract

Increasing demand for Multi Chip Module (MCM) Power devices in a Quad Flat Non-leaded (QFN) package outline drives the development of the LFCSPs-P (Lead Frame Chip Scale Package-saw-Power). Multi Chip Module offers host benefit including performance improvements such as shorter interconnect lengths between dies, lower power supply inductance and lower off-chip driver. Besides, it can reduce the manufacturing cost and increase the utility of programmable systems [1]. Compared to the leaded package with similar body sizes and lead counts, QFN offers far superior thermal performance and provides excellent electrical characteristics [2]. Package designers used nominal thickness of standard Cu-Alloy leadframe and standard package height meant for power packages with soft solder die attach and heavy Al wire bonding to enhance heat dissipation capability other than the heat sinks. Map type design is used to enhance productivity by maximizing the device density. Singulation is achieved by sawing through the molded leadframe channels with diamond type blades that separated the arrays rows and columns [2]. However, the combination of ductile and brittle material in the same sawing process creates real challenges in term of sawing quality, blade life and throughput. Experiments were carried out and its results show that integration of the blade type, parameters, methodology and other external features give the maximum result for the said challenges

1. Introduction

Power LFCSP development is being carried out in STATS ChipPAC Malaysia for 12x12mm package size. The device for this package is a highly integrated self-protected power switch that designed to replace electromechanical relays, fuses and other discrete devices in embedded systems specialized in the power management, commercial and automotive applications [1].

Fig. 1 Saw Singulation Process

Saw singulation is the most challenging process to meet both quality and cost targets. Clear trend shows the reduction in package size and continuous tightening of cut quality specifications. LFCSPs-P substrates are made from composite materials with different hardness and brittleness characteristics that interact very differently with the dicing blade [3].

The molding compound is relatively brittle compared to the copper leadframe and it requires specially formulated blade that must constantly expose new diamonds to the cut interface [4]. The main quality issue associated with the brittle molding is chipping along the edges of the diced kerf. Silica particles in the polymer-molding compound are used as a stabilizer to minimize the stresses and to control the flatness of the substrate [5]. The size of the silica particles affects the size of chipping which larger silica particles will cause larger chipping on the molding. The silica grit pull out mainly causes this phenomenon from the molding during sawing process. The current customer specification for chipping of the molding is on the order of 50 micron [4].

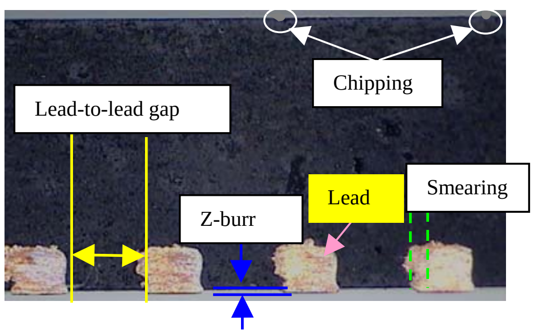


Fig. 2 Cutting Quality

The quality issues related to the copper components are smearing of the ductile copper and the formation of burrs. 50 micron is the upper limit for the copper burrs that may protrude from the leads in the dicing direction ('x-burrs') or in either of the two perpendicular directions ('y-burrs' and z-burrs'). A generally acceptable measure of smearing between leads is 25% of the lead-to-lead distance [3].

Feed rate gives direct impact of throughput in the sawing process, which the dicing blade progresses through the substrate. From this experiment, the blade feed rate need to be as low as possible to avoid severe Cu smearing and to control the blade wear rate. The challenge here is how to get higher throughput while maintaining the quality on the sawn units. For the worn blade especially on the lateral direction, package X-Y dimensions will be affected. Results show that package dimension tends to shift to the upper limit after a few meters run. Comparison between the high wear rate Soft blade, Medium Hard blade and low wear rate Full Hard blade is also being done. The high wear blades are good to maintain the X-Y dimension to within the specification. This is because the vertical wear is faster than lateral wear, thus it will ensure the X-Y dimension tolerance is well within the specification limit.. The trade-off of using higher wear blades is the machine downtime due to frequent blade replacements.

2. Substrate Design

Minimizing the amount of copper that the dicing blade will face is a key element that should drive the substrate design [5]. Half etching at all sawing line is commonly used. Then, the lead cross section at the dicing area needs to be as small as possible to minimize the smearing between leads. These design will minimize the loads which could be observed through spindle load monitor. Lower the loads will produce higher throughputs, higher yields, better cut quality and increase blade life [5].

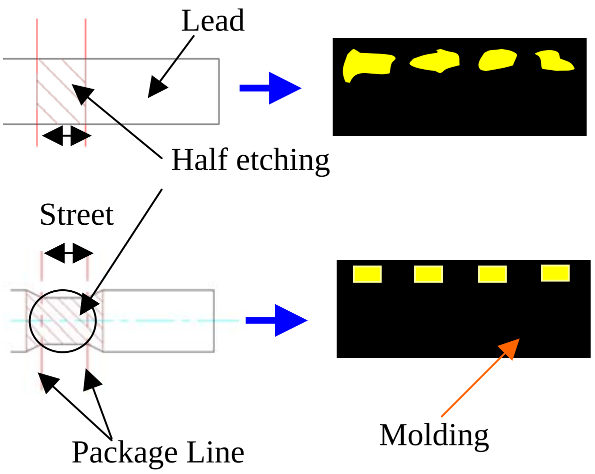


Fig. 3 Substrate Design

Designing the mold as close as possible to the copper leadframe edge is important to reduce the unsupported area. This will minimize any blade vibration and breakage during the dicing process [5].

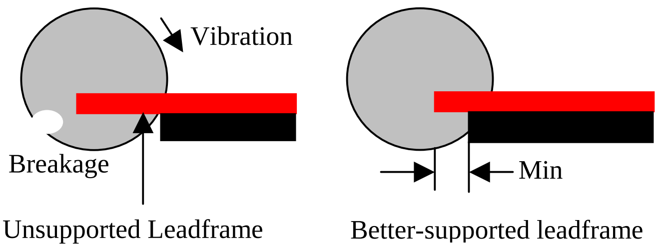


Fig. 4 Less Vibration Mold design

3. Selection of blade type

For this evaluation on the tape based sawing, 3 different blade types are used, i.e. Full Hard , Medium Hard & Soft blade. For each blade, the outer diameter (OD), thickness difference & diamond grit size are evaluated at both high and low value taken from internal specifications. All blades have the same number of slits and diamond concentration percentage. All options are using the same feed rate and spindle rotation speed. All substrates are sawn with single pass method with an optimized molding compound filler size. The responses are X-Y dimension, Z-burr, lead-to-lead gap, chipping and wear rate. Results are as follows;

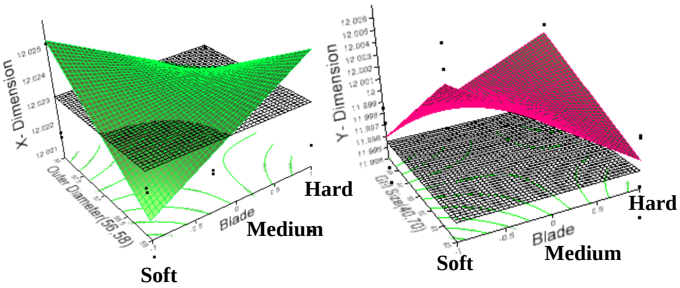


Fig. 5 X-Y dimension to Blade Type, OD & Grit Size Characteristic

Results show that for X-dimension, all blades are within specification. Among all the blades, Low OD Soft blade gives the best performance. Same as for the Y-dimension, all 3 blades give a similar reading. Medium Hard blade with a nominal grit size value shows the closest reading to 12mm.

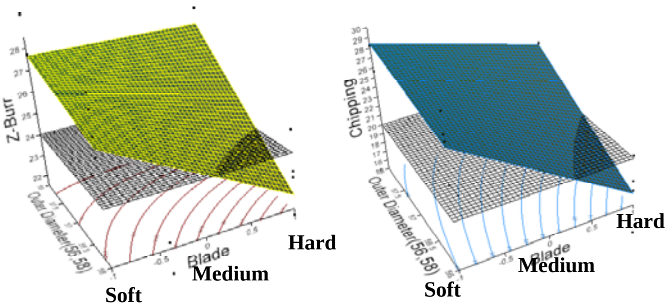


Fig. 6 Z-Burr and Chipping relation to OD and Blade

Results show significantly lower Z-burr and chipping when using Low OD Full Hard blade.

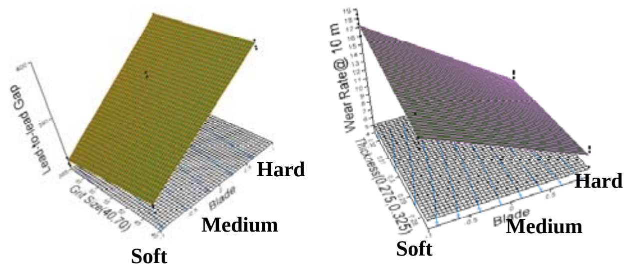


Fig. 7 Lead-to-Lead gap & Wear Rate to Grit Size & Blade Type Characteristic.

Lead-to-lead gap increased when using Full Hard blade, with nominal grit size. Wear rate is significantly high for Soft blade. The wear rate of Medium Hard blade is between the other two blades.

Based on this result, Full Hard blade with Low OD, nominal grit size show the best result for these critical responses. The blade thickness that is selected for the parameters optimization run is the same with the leadframe kerf width size based on the lead-to-lead gap result.

4. Parameters

For the next evaluation, feed rate, spindle speed (rpm), cutting depth and chilled water temperature will be evaluated. The results are as follows;

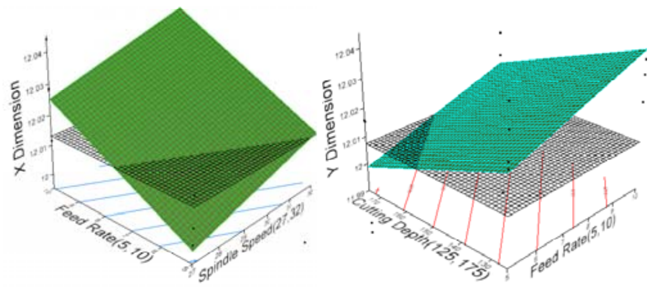


Fig. 8 X-Y dimension to Feed Rate, Spindle Speed and Cutting Depth Characteristic

From the data, low feed rate with nominal rpm spindle speed and deeper cutting through tape give the best result to the X-Y dimensions.

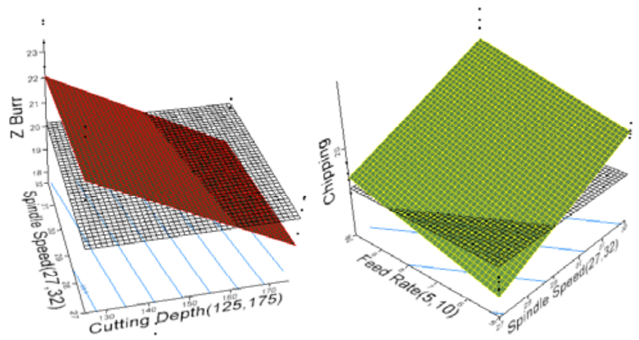


Fig. 9 Z-Burr and Chipping to Spindle Speed, Cutting Depth and Feed Rate Characteristic

Result shows a nominal rpm spindle speed with low feed rate and deeper cutting through tape can reduce Z burr and package chipping.

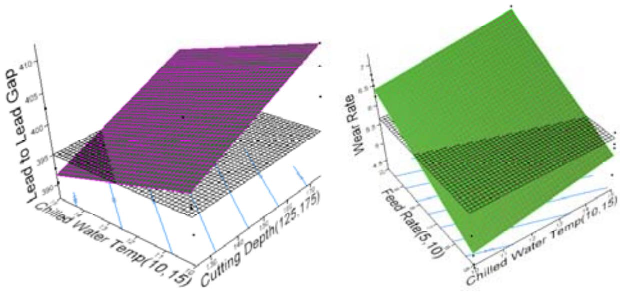


Fig. 10 Lead Gap and Wear Rate to Chilled Water Temperature, Cutting Depth and Feed Rate Characteristic.

From the data, applying lower feed rate with deeper cutting depth through tape and low chilled water temperature give a better result to the lead to lead gap by reducing Cu smearing which will lower the wear rate for the blade.

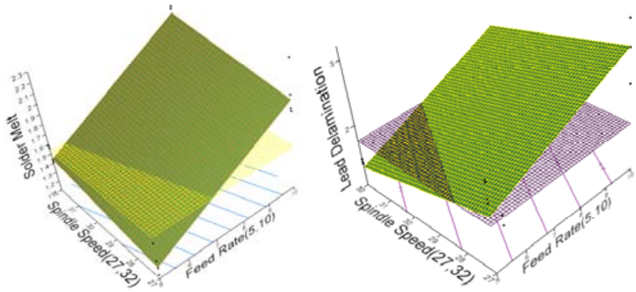
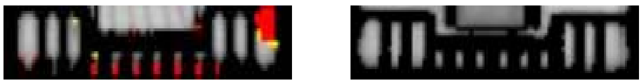


Fig. 11 Solder Melt and Lead Delamination to Spindle Speed and Feed Rate Characteristic

Result shows lower feed rate with nominal rpm spindle speed has the lowest solder melt and lead delamination for the package.



(a) Lead Delamination (b) No Lead Delamination

Fig. 12 Lead Delamination

From the above discussion, it is summarized that :

a. Maximum feed rate is set at center point to maintain the cutting quality within the specification. This also produces lower wear rate to maintain longer blade life.

b. Spindle speed need to be maintained at nominal point after considering the chipping, Z-burr, lead delamination and solder melt.

c. Cutting depth needs to be 85%~90% of the tape thickness, to get the best result of X-Y dimension, Z-Burr and Lead-to-lead gap.

d. Chilled water temperature is also a key factor to minimize the Cu smearing which effect the lead-to-lead gap, reduce the wear rate and to reduce Z-burr.

5. Optimizing with the methodology

By using the information from previous experiment, optimization is being carried out by adding chemical into the city water to reduce the surface tension and the water will spread more to the substrate surface during cutting. The output for this evaluation is the Z-burr and lead-to-lead gap.

Below is the result from this experiment.

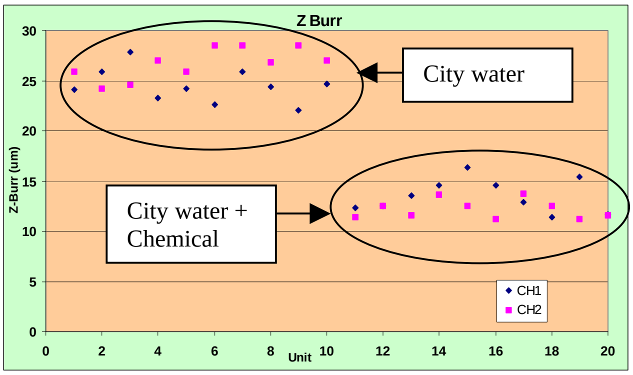


Fig. 13 Z-Burr characteristic after adding chemical into the city water

Based on the result, it shows a reduction on the Z-burr for both sides; X dimension (Ch1) and Y dimension (Ch2) by adding chemical into the city water compared to only normal city water.

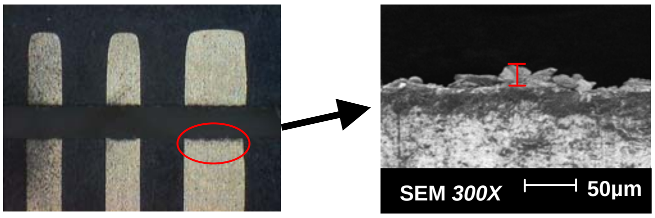


Fig. 14 Z Burr Width

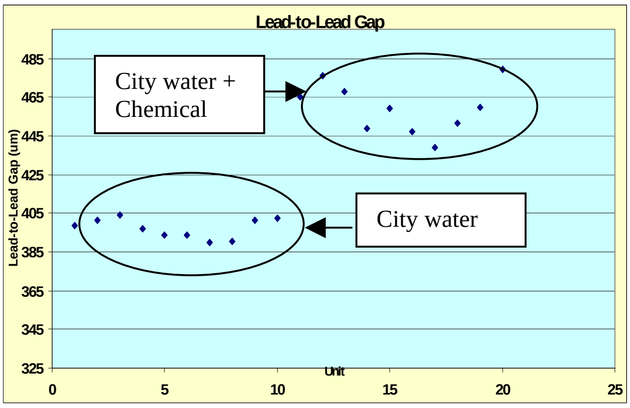


Fig. 15 Lead-to-lead gap characteristic after adding chemical into the city water

Result also shows significantly bigger lead to lead gap by adding chemical into the water compared to the normal water.

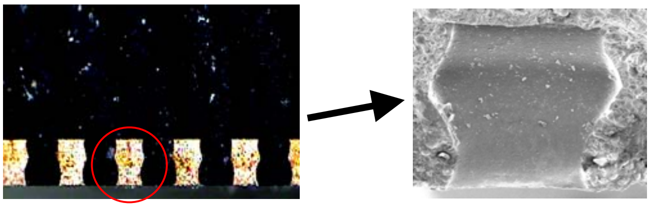


Fig. 16 Width of metal on the sidewall quality by adding chemical into the city water

6. Discussion

From the blade selection experiment, Full Hard blade with Low OD shows lesser chipping and lower Z-Burr, while the Soft blade shows the better cutting quality with smooth surface but shorter blade life. For the High OD, we could see some level of vibration by looking at the surface roughness and Cu smearing compared to Low OD. Thus, we understand that blade exposure also pose as a factor to determine good cutting quality. By using a thinner blade, X-Y dimensions tend to move to the upper limit after a certain distance run. This is due to higher wear rate on the lateral side compared to the vertical side. It is also known that blade thickness exceeding the kerf width will cause extra sawing at each side of the package, which will result in closer lead-to-lead gap as the width of metal on the side wall increased. Theoretically, Full Hard blade with slits is giving freer cutting with fewer loads since the contact surface with the substrate is lesser and improving cooling of both blades and substrate by allowing the coolant to flow through it.

As for the diamond grit, even though smaller grit give better chipping result, feed rate need to be as low as possible to maintain the quality of the cutting. This is because the faster feed rate, the higher possibility of the small diamond to be detached. Thus nominal grit size is the optimum size to maintain acceptance level of quality and throughput. Dressing is also applied to Ni blade at initial and interval cutting to machine off the excess binder material, release diamond particles and remove Cu debris that accumulated inside the pocket on the blade which increase the spindle current load. Blade spindle rotation speed is a factor for the Sn plating melt, delamination at lead and the Cu debris on the compound surface. From this study, nominal value of spindle rotation speed is the most optimal value for this substrate. If the rpm is higher, it will increase the throughput slightly but the trade off because of the significant increase in friction and blade heat up will be blade life reduction and increasing the risk of heat fractures and breakage. Chilled water is used to cool down the blade and substrate during cutting as the temperature is about 300ºC ~700ºC when cutting. Chilled water is also used to clean the abrasive particles formed during cutting and also as a lubricant to keep the edge clean. The purpose of adding chemical into the chilled water is to reduce the surface tension thus a lot more area is covered by the chilled water.

It gives impact on cutting quality mainly in the extent of lead smearing and Z-burr as shown in Fig. 13~16. It helps to cool down and lubricate the blade which would minimize the loads during sawing process.

The methodology when cutting with dual spindles at the optimized feed rate, chilled coolant additive as an alternative to water, single pass cut through the package and the blade cut to 85%~90% into the tape give a better combination for improvement. With a deeper cutting to the tape, the spindle load will be lower as the contact surface of the blade and the substrate during cutting is lesser as shown in Fig. 17. Evaluation with jig saw, which could go far deeper compared to current process will be carried out to further understand the effect of deeper cutting. In the experiment done earlier, cutting the surrounding rim, which is full metal, with a dedicated blade gives a better control to the wear rate. This is because the second blade will only cut the half etch Cu. This method cannot be implemented to the tape based sawing, as the surrounding rim will still stick to the adhesive tape after cut. For the jig saw which only the units is being hold by the vacuum, the metal will drop from the nest leaving only the units.

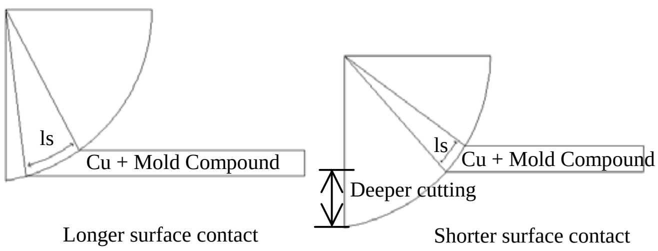


Fig. 17 Contact length difference to substrate by different cutting depth

7. Conclusions

From the experiment we can conclude that:

i. Substrate design is important to ensure the higher quality, longer blade life and throughput.

ii. Full Hard bonding material blade type with slits, blade thickness is the same as the saw street width and optimum exposure could be used to cut the substrate of thick Cu-alloy leadframe and standard power package height.

iii. By setting the feed rate at center point, nominal rpm spindle speed, cut 85%~90% through the tape give the best combination to the quality, throughputs and wear rate of the blade

iv. Methodology to cut this substrate by removing the outer rim with a dedicated blade, single pass cut for both channels, dressing at initial/interval and adding the chemical to the city water to further reduced the temperature at the contact point could help to solve some of the problems.

v. Combination of Hard & Soft blade for the higher quality of the cutting and jig saw to cut deeper through the substrate is expected to be the best combination for future evaluation.

Acknowledgments

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