Original Research Article

Pick and Place Process Optimization for Thin Semiconductor Packages

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ABSTRACT

Nowadays, Electronic manufacturers trend are to become thinner and thinner especially those electronic gadgets that are very handy and convenient on our daily necessity. Challenge with the leading manufacturers in the production and development of less size gadget yet with the richness of available application and uses that we can work on with what can please its consumer for their convenience and satisfaction. As with the semiconductor company, the correlation between becoming thinner versus manufacturing capability become significantly opposite, as the package becomes thinner the more complex its related process can be. This study covers an innovative approach in Die Attach station on critical handling of thin die packages. Lessons and learning were documented from Ball Grid Array (BGA) packages as first to be evaluated with thin package requirements. Also discussed herewith are documented defects and related issues during trials and die attach builds that have been a show stopper on its early production.

Keywords: Pick and place; pick-up tool; DAF; die attach; diebonder

1. INTRODUCTION

In the fast- paced semiconductor industry the need for package solution arises in order to cope with emerging miniaturization trend (Abdullah et al., 2012). During the early proposal and review of the packages invites various question and inquiry if the existing Die Attach machine platforms and capability can satisfy the requirements of the package. Complexity with the package requirements is one challenge to all team members to come up with an innovative solution in dealing with the issue. Also, one big challenge given is maximizing the available resources to minimize the possible defects related factor.

The key factor that determines the size of electronic assemblies is packaging density. One way to increase the packaging density is to decrease the size of passive components and the clearance required between them (Wang et al., 2007).

On the initial evaluation of the project addressed, major show stopper matters, commonly die crack issue evident during separation of die to tape that is one topping all the Pareto of defects. Planning on eliminating the issue is one of the major targets that all was focus to. During the qualification review it was found that standard pick and place was not efficient in producing good response in terms of die crack. Deriving on risk assessment and planning based on early results shows clues on wise judgment in coming up with a selection which of all the factors has major effect.

By deeply analyzing the outcomes, results to breakdowns with the proper selection of machine, correct wafer treatment and process, modification of indirect materials, parameter adjustment and formulation of special instruction in handling thin die packages.

1.1 Project Statement

This presentation focuses on understanding the cause and main contributor to die crack defect at die attach stations. Comparison of standard pick and place versus improved pick sequence. Analyzing the behaviour of defect and provision of innovative solution and improvement on existing machine capability for robust processing of thin packages. Documentations of early experience in engineering build and evaluation for thin packages processing. Assessment of actions and improvement based on the result of the table of the experiment.

This study covers only early experience in processing of thin die packages based on engineering and line stressing results. Modification of indirect materials and improvement in pick sequence using platforms with "distance to die" setting. The presentation does not include wafer details. Also, the pre-assembly process that the wafer has undergone is also not stated within the presentation. The focus only of the presentation covers die attach stations, process setting and improvement on indirect materials.

2. REVIEW OF RELATED LITERATURE

Three critical processes of SPPD earlier identified are the Wafer Saw, Mold, and Final Test processes. Details of each critical process and their corresponding top reject contributor are further discussed in this chapter.

2.1 Standard Pick and Place Sequence and Setup

Pick and place sequence, emphasizes on the synchronous upward movement of the bond head and needle with regards to individually cut die. The individual die was separated into the wafer tape by the ejection movement of the needle against the vacuum hold wafer tape.

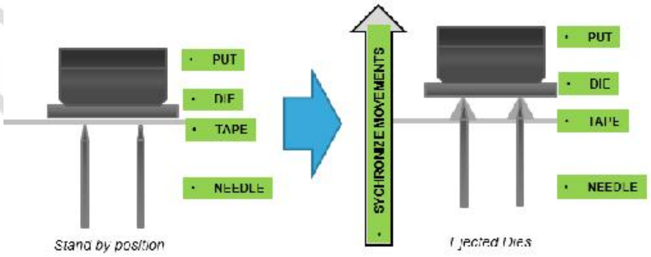

Fig. 1. Bond head movement from standby height position until individual die are ejected by the needle during synchronous pick sequence

For standard pick and place procedure, needle and pick-up tool (PUT) are the primary indirect materials used to pick the individual die from the tape.

Commonly in the die attach materials, PUT covers 70-90 percent of the total die size and ejector design configuration with an exact outline as compared with the dimension of the die. Furthermore, applicable indirect materials will differ according to the actual die construction and requirements.

For machine set-up procedure, pick and place includes "Teach Z Height" parameter to ensure an accurate distance of the PUT to the actual die top surface. These can be performed through recipe "teach" setting, using these procedure machine bondarm Z travel is computed automatically by the actual reference height distance from die surface to bondarm standby position.

Through a standard pick and place set-up, needle reference height positions are taught on the bottom solid part of the die. Based on figure #2 needle is located underneath the die and tape interface. (See figure#2 for machine reference positioning).

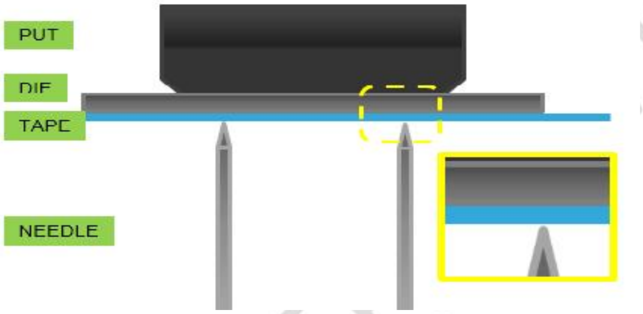

Fig. 2. Position of needle on standard packages

In Comparison with die attach films (DAF) packages, needle positioning is beneath the bottom part of the die due to the soft structure of the DAF that during "Z height" learning needle will protrude to the tape and pierced through the DAF since the tape has no solid body.

Based on figure #3 illustration, for DAF package processing needle are located under the die during standby height position.

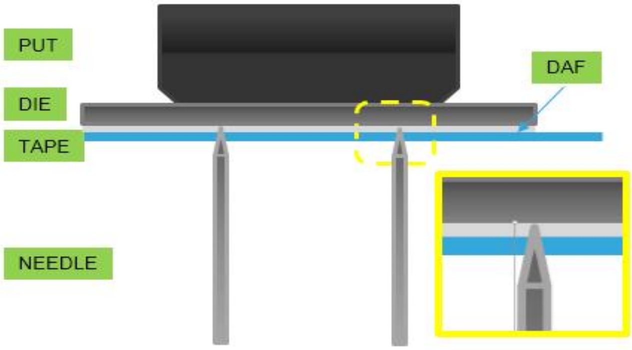

Fig. 3. Position of the needle with DAF packages

During ejector wait height position, die are seated above the ejector needles. For standard pick sequence, dies from wafer tapes were separated during eject up the movement of the needle together with the supply of vacuum at pepper pot. There is a tendency that the wafer tape is sucked up above the flat surface of the pepper pot and will be held during needle movement. Simultaneous to vacuum suction, the needle will move upward to separate the die from the tape. Dice during needle sequence is supported above by a levelled pick-up tool on top of the die, this is provided with a vacuum to avoid shifting during the picking up sequence. Afterwards, all picked dies will be transferred or placed to lead frame or substrate.

2.2 Indirect Material versus Standard Pick and Place

This section explains the relationship between indirect material during the pick sequence. Common indirect materials adapted at standard processing is designed having relief or large hollow centre portions. These were used to maximize the vacuum needed to hold the die during the pick. For die attach process, it is necessary to have enough vacuum too stably hold the die during the movement.

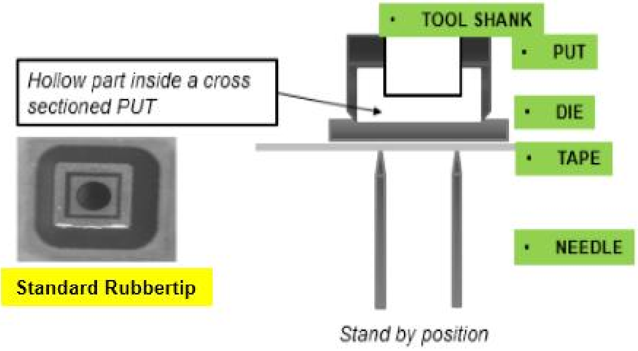

Fig. 4. Cross section of pick up tool used on standard pick and place

Problem with standard indirect materials and pick sequence as shown in illustration figure #4 is observed with high risk for die breakage due to the no equivalent support parallel with the needle location. (for DAF packages needle are protruded).

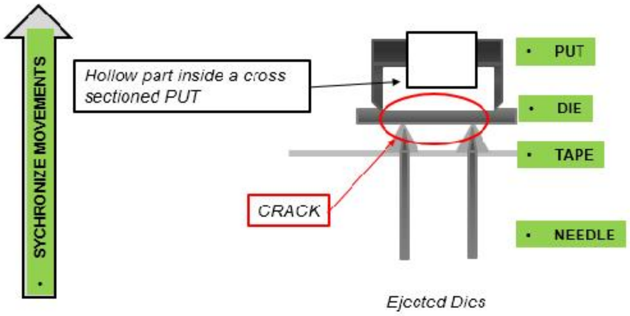

Fig. 5. Cross section of pick up tool used on standard pick and place. (Eject-up movements)

Based on the illustration in figure #5, fulcrum effect was encountered during needle ejection movement due to the bias needle and PUT configuration. The defect manifestation evident at needle location and localization shows cracking in series with needle location both observed vertically on top and bottom part of the die.

1.3 Modification in Indirect Materials

By deeply analyzing the defect signature, modification on indirect materials and improving the standard pick sequence has an upright course in providing the innovative solution for thin packages.

Changing the current design of the indirect materials needed in processing such a pickup tool from standard design (with relief) to full contact pick-up tool eliminates bias top support versus needle location.

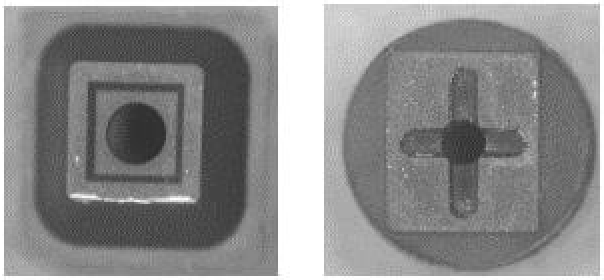

Fig. 6. Standard rubber tip (left), and full contact rubber tip (right)

Full contact design ensures parallel support at needle location and pick-up tool, during ejector movement needle will fall on the solid part of the pick-up tool giving upward relief to fulcrum effect during the picking process.

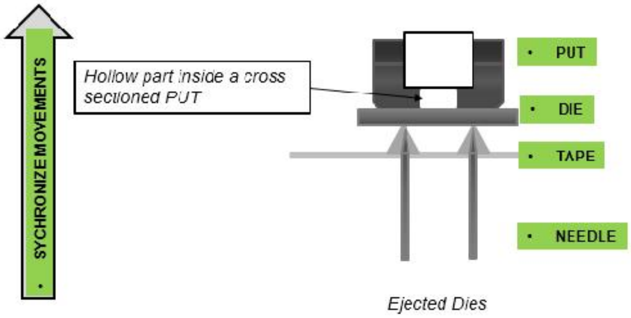

Fig. 7. Cross-sectioned area of full contact rubber tip inlined with the needle location

Based on the principle of the new design, bending of the die which is contributed by the hollow portion from standard PUT design is minimized or eliminated. By this elimination, primarily enhances the facility of the structure of the die at pick position.

1.4 New Pick-up Sequence (Distance to Die)

Standard pick sequence using full contact PUT resulted with high risk to stress the die due to the possible deviation at bondhead and needle motors, because of its inherent variation. The position of bondhead and needle can deviate into minimal machine tolerances. This was proven to be detrimental to die since thinning of die made it less resistant to breakage.

In addition, due to the package construction, DAF material is considered for thin packages. Based on the machine response, the needle is protruded during "teach Z position". These shows that die will be seating above the protruded needle during the pick sequence of the machine. As said earlier, there is minimal deviation on pick z height. To summarize, standard pick and place have high risk in cracking or breakage due to observed possible contributing factors.

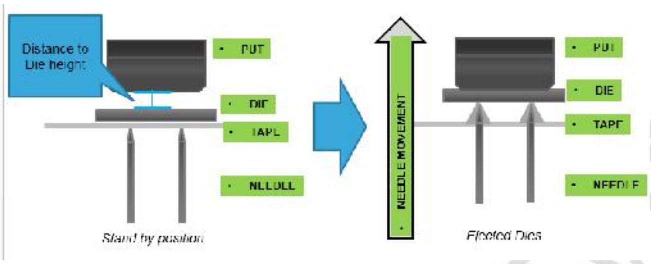

Fig. 8. Pick-up sequence with the addition of distance to die

By the addition of "distance to die" parameter to pick up sequence results to pick up tool that will situate above the die without direct contact on the surface. With these, no counter influence during movement of ejector from "stand by" to reference height.

During needle ejection from the reference height position, the needle will push the die upward until "distance to die" height will be met. By the result, direct contact of the PUT to die during pick sequence is eliminated. There will be no collision between die, needle and PUT during pick position. By these responses, micro crack possibility during pick can be avoided done by providing enough distance during the pick process.

2. EXPERIMENTAL SECTION

The study covers 2 die sizes to be used as test subjects in the study. Both are divided into rectangular and symmetrical type of die. Since the experiment covers thin packages, DAF was used as adhesives in bonding the individual die to the substrate.

Table 1. Die evaluation

Type of Die	Die Size	Adhesive
Rectangular	2.0 x 3.0 mm	DAF
Symmetrical	2.5 x 2.5 mm	DAF

The initial matrix shows both die sizes to be subjected with different PUT and distance to die parameter.

Table 2. DOE matrix for evaluation

Type of Die	Die Size	Pick-up Tool	Distance to Die
Rectangular	2.0 x 3.0 mm	Full	No

Symmetrical	2.5 x 2.5 mm	Full	Yes No Yes

Three "distance to die parameters" were tested to analyze which of the given selection will result in the robust parameter.

Table 3. Distance to die parameter

Parameter	Distance to Die
# 1	A
# 2	B
# 3	C

3. RESULTS AND ANALYSIS

All experiment has undergone separate legs of an experiment in determining the most effective parameter to be set as an initial reference.

The table below shows the result of the comparison for full contact and standard rubber tip in terms of defects occurrence during pick and place processing.

Table 4. Die evaluation

Die Size	Pick-up Tool	Remarks
Rectangular	Standard	Frequent die crack and miss-pick issues
	Full Contact	Fewer evidence of die crack and miss-pick defects
Symmetrical	Standard	Frequent die crack and miss-pick issues
	Full Contact	Fewer evidence of die crack and miss-pick defects

Based on the table of experiment both symmetrical and rectangular package has evidence of die crack issue given with no distance to die parameter. But comparing the occurrence of defect results that full contact is better compared with standard rubber tip.

3.1 Design of Experiments

Design of experiment (DOE) includes the occurrence of the defect through the processing of thin packages. Miss picked and die crack is the main defect measured. These were chosen due to its correlation with the implementation of improvement for indirect material and pick sequence.

Experiment applies full contact PUT for symmetrical and rectangular dies these are in compliance with the primary result of comparison of indirect materials.

Table 5. DOE evaluation result

Die Size	Pick-up Tool	Distance to Die	Miss Pick	Die Crack
Rectangular	Full Contact	A	x	
		B		
		C		x
Symmetrical	Full Contact	A	x	
		B		
		C		x

Based on the table above, both symmetrical and rectangular dies were tested with three type of “distance to die” parameters. Based on the result parameter #2 has the best response according to the defect manifestation results and in comparison with different parameters. Both die size of the experiment shows good response that can be achieved during the implementation of parameter #2 in addition with defined put configuration. Furthermore, experiment is justified by the tally of defect occurrence. Other pick parameters were not alter during the experiment to avoid noises during the trial.

3.2 Line Stressing Results

During the line stressing and production of larger quantity, defects are monitored and recorded based on its' occurrence and tallied with the number of rejected units according to the defect designation. Table below shows the breakdown of die crack from WWK1522-WWK1553. Scope includes early line stressing and production for thin packages.

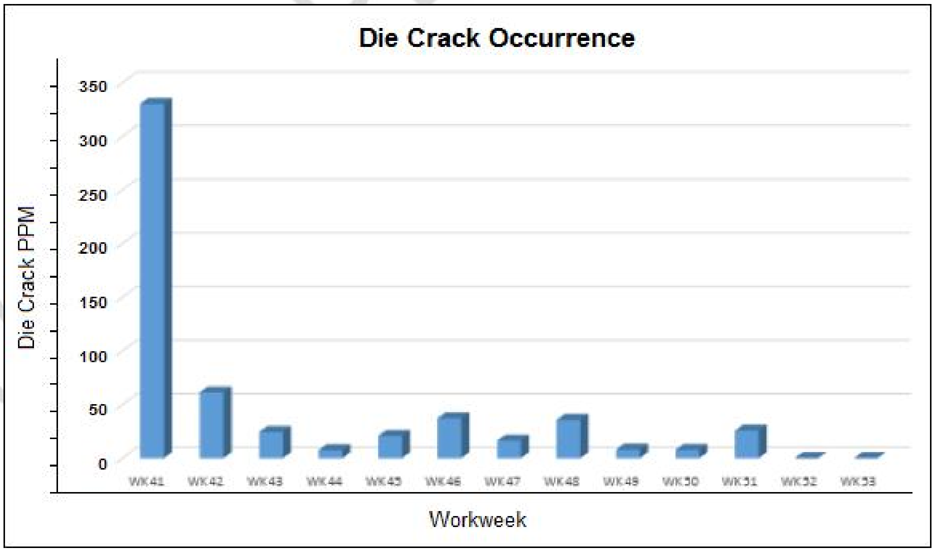

Fig. 9. Die crack trend

Based on the die crack trend, the average die crack occurrence falls to 20 PPM for the last quarter of the year. Stabilized production improvement was observed during wk43 after defining the robust condition for die attach process. Shown in Fig.10 is the Pareto of manufacturing rejects for thin packages.

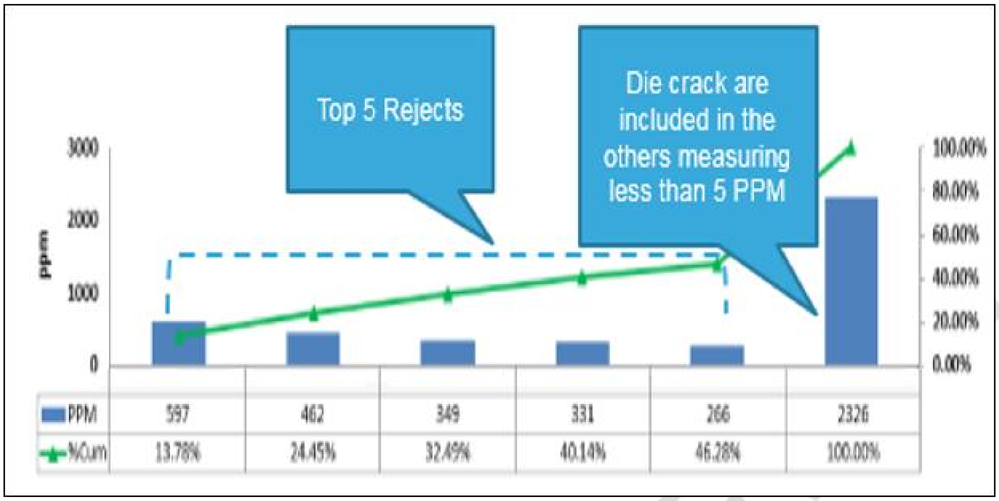

Fig. 10. Pareto diagram of manufacturing defects of think packages.

Based on the latest manufacturing result dated WWK1604. Die crack at die attach station is measured less than 5 PPM based on the overall manufacturing rejects. The result shows that during the implementation of robust process and parameter flow at Pre-assembly and Die attach, die crack is measured not on the alarming level.

4. CONCLUSION AND RECOMMENDATIONS

This study concludes that thin packages are very prone to thinning related defect such as die crack. Due to the thinning, die became less resistant to breakage. Moreover, considering the existing machine capability and indirect materials available with the production resources it was observed to have a high risk to manifest defects. Full contact rubber tip shows better improvement in minimizing the observed fulcrum effect on a standard pick and place sequence. Result with the comparison of standard and full contact rubber tip shows that full contact is better in terms of defect manifestation. Improved materials and machine sequence are applicable both with symmetrical and rectangular die dimension. Given that proper design configuration must be considered. The study covers the existing machine platform for BGA packages only. By qualification of the higher end machine platforms can just offer a better response. Newest rubber machine platforms includes better die handling technology use in a much safer pick processing. Also, exploration of related additional pick parameter that can be helpful with the improvement of die handling.

Implementation of defined indirect material and pick setting is applicable with machine platforms with "distance to die" setting. Furthermore, evaluation with small and large die size is recommended. The suggested setting can be considered for the qualification. It is also highly recommended, if not necessary, that the assembly manufacturing processes observe proper ESD controls. Opportunities presented in [6], [7] could be very useful to help ensure ESD check and controls. Ultimately, continuous improvement is important for sustaining the quality excellence of any product and of the manufacturing assembly and test plant.

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Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by the personal efforts of the authors.

REFERENCES

1. May GS, Spanos CJ. Fundamentals of semiconductor manufacturing and process control. 1st ed., Wiley-IEEE Press, USA; May 2006.
2. Doering R, Nishi Y. Handbook of semiconductor manufacturing technology. 2nd ed., CRC Press, USA; July 2007.
3. Geng H. Semiconductor manufacturing handbook. 1st ed., McGraw-Hill Education, USA; May 2005.
4. ESEC 2008 diebonder machine operations manual.
5. SAS Institute Inc. JMP statistical discovery software. https://www.jmp.com/en_ph/software.html
6. Gomez FR, Mangaoang T. Elimination of ESD events and optimizing waterjet deflash process for reduction of leakage current failures on QFN-mr leadframe devices. Journal of Electrical Engineering, David Publishing Co., vol. 6, no. 4, pp. 238-243; July 2018.
7. Gomez FR. Improvement on leakage current performance of semiconductor IC packages by eliminating ESD events. Asian Journal of Engineering and Technology, vol. 6, no.5; October 2018.

8. Abdullah, Z., Vigneswaran, L., Ang, A., & Yuan, G. Z. (2012, November). Die attach capability on ultra thin wafer thickness for power semiconductor. In *2012 35th IEEE/CPMT International Electronics Manufacturing Technology Conference (IEMT)* (pp. 1-5). IEEE.

9. Wang, Y., Olorunyomi, M., Dahlberg, M., Djurovic, Z., Anderson, J., & Liu, J. (2007). Process and pad design optimization for 01005 passive component surface mount assembly. *Soldering & surface mount technology*, *19*(1), 34-44.