BRIDGE PICK TOOL MODIFICATION ON DACA MACHINES FOR TILTED CLIP AND CRACK DIE REJECT REDUCTION

[1]Harold L. Gutlay
[2]John Rhyan R. Llamas

Nexperia Philippines, Philippines Avenue, Light Industry and Science Park 1, Brgy. Diezmo, Cabuyao City, Laguna, 4025 Philippines
[1]harold.gutlay@nexperia.com; [2]john.rhyan.llamas@nexperia.com

ABSTRACT

Die attach is a semiconductor assembly process in which singulated dies are picked and attached to the solder-applied lead frames. Clip bonding process is also part of the semiconductor assembly process wherein a copper clip is attached to the top of die from previous die attach process. These processes interact with each other as the clip is in contact with the die through solder. Die crack is a critical failure in die attach and clip bonding process which has been the top contributor of customer complaints since 2017. Die cracks occur due to mechanical stresses causing fractures on the die surface. This paper analyzes the stresses exerted on the die during clip bonding in terms of crack die rejects. The parameters that were studied were bond force, crack die, and tilted clip. Bond force has a positive correlation with crack die and a negative correlation with tilted clip. The cracks were found to propagate through contact points of the clip in the form of the clip dimples. Reducing the contact points of the clip and tool through recessing the auxiliary planes of the bridge pick tools by 55um helped reduce the stress exerted on the die during clip bonding by 46%. The reduction of height to only the auxiliary planes of the tool allowed the clip to move during bonding while still maintaining high bond force for clip placement, this resulted to improvement on both crack die and tilted clip by 50% in terms of defective parts per million.

1. 0 INTRODUCTION

1.1 Clip Bonding Process

Clip bonding process is the process of attaching the copper clip onto the top of the die with solder dispensed from the previous process step. This clip provides both electrical and thermal contact to the active circuitry of the die. The clip is singulated and picked up by the bridge pick tool which uses vacuum pressure to hold the clips. Figure 1 below shows the bridge pick tool which also has auxiliary planes to hold the clip.

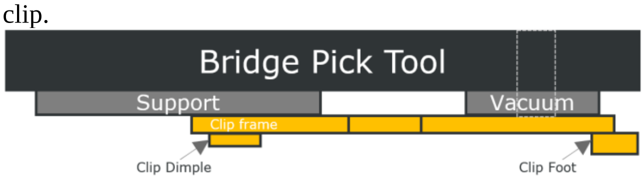

Fig. 1. Side view of bridge pick tool showing interface of clip and tool contacts.

The clip dimple touches down on the solder on top of die while the clip foot touches down on the solder on top of the bottom frame. The clip dimple creates a reservoir for the solder to flow to avoid the occurrence of solder overflow or solder creep causing possible shorts, it also affects the overall stacking height of the unit. The clip foot sets the clip in position, locking in its position to avoid any tilting or misalignment of the clip.

Clip bonding is done by lowering the bridge pick tool with clip onto the die with solder surface, the bridge pick tool releases its hold on the clip after an installed contact sensor is opened shown on Figure 2. The contact sensor open trigger is controlled by the set bond force. Bond force is set by tightening or loosening a spring inside the clip bonder bond head assembly.

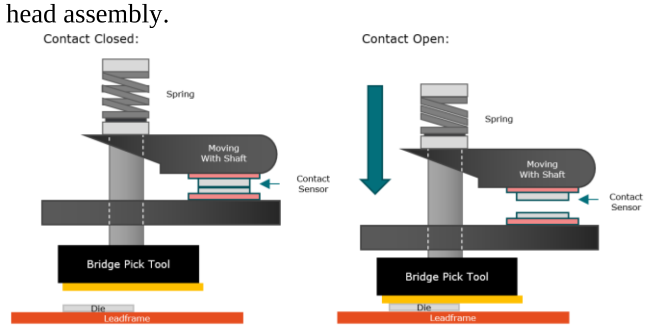

Fig. 2. Clip bonder bond head mechanism and release sequence

1.2 Die Crack

Die crack is one of the failures of silicon due to its brittle nature. Die crack also makes dies prone to propagation and ultimately separation of the die (Macaspac et. al, 2020). Because of this nature, mechanical stresses induced onto the die can cause cracks.

1.2.1 Die Crack in Clipbonding

During this clip bond process, stress is exerted on the die specifically on the areas where the clip dimple is present. The force needed to release the contact is transferred to the clip and die surface.

2.0 METHODOLOGY

2.1 Understanding the Crack Rejects
2.1.1 Force Exerted by Clip Dimple

Proof of concept for the hypothesis was done using one of the die sizes from the crack feedbacks. SOT1205 units with 3.30 by 1.75 millimeter die size were used. Using the standalone bridge pick tool, excessive force was applied to units.

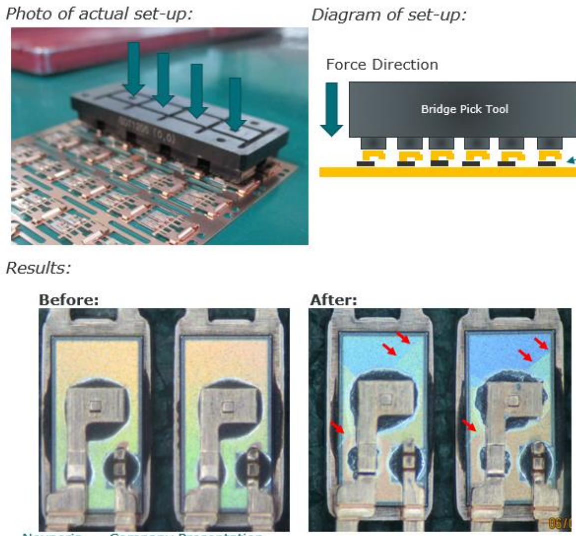

Fig. 4. Force trial on die (Crack Simulation at DACA)

On figure 4, force crack on die with clip using detached bridge pick tool and applying manual force. 2 out of 10 units subjected to the force reject trials, these units manifested cracks.

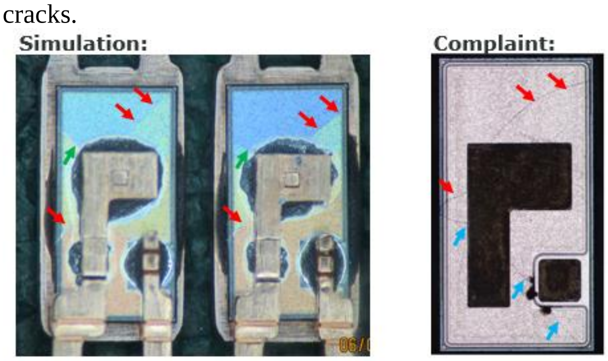

Fig. 5. Force trial on die (Crack Simulation at DACA)

In figure 5, the crack lines of the simulation units and the feedback unit are comparable, with one crack traversing from the left of die to the right of die and still passing through the clip dimple. This simulation validated that with excessive force, the feedback cracks are plausible.

2.1.2 Die Strength

Die strength is the measure of how much force the die can withstand before the point of yielding or fracture. Die strength measurement was performed using an Instron machine, a universal testing machine designed to apply different loads to a specimen with interchangeable tips. Die samples used was standard die thickness of 150 micrometers with a dimension of 3.9 by 3.00 millimeters. For the die strength test, Die was subjected to three-point bend test with a tool of 7 by 0.5 millimeter. There were 10 legs with 10 individual dies. The force used was from 1 Newtons to 10 Newtons.

Die strength test showed observed visible die crack at 8 Newtons. This force is equivalent to axial stress of 4.85 Megapascal.

2.2 IMPACT OF CLIP BONDING ON DIE
2.2.1 STACK ANALYSIS

2.2 Impact of Clip Bonding on Die
2.2.1 Stack Analysis

Stack analysis was done to verify the possibility of force exertion on the die during the clip bonding process. Taking the higher limit of package stacking height specified in the documented control plan, which is 0.56 millimeter, it was compared to the worst-case scenario for clip dimensions. Stack analysis illustrated on figure 6 shows that using these parameters, the clip is floating on the unit by 0.052 millimeter on the clip foot, leading to tilted or sway clip. To compensate this, a possible action is to increase the bond force to further embed the clip onto the bottom frame. This increase of bond force leads to possible excessive forces exerted on the die.

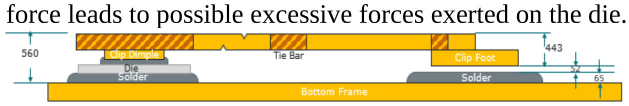

Fig. 6. Stack analysis of die and clip system

2.2.2 Die Stress from Bridge Tool

Calculations were made for the stress applied onto the die with the current design of bridge pick tool which has direct contact with the clip during bonding. Using moment equation, it was found that the stress experienced by the die is 7.47 Megapascal, much higher than the 4.85 Megapascal breaking point.

$$\textbf{Summation of Moment} = 0$$

$$0.625\,R1 - (0.625 + 0.05)(166.67\,x\,1.35) - (0.625 + 0.05 + 3.50)(166.67\,x\,1.65) + (0.625 + 0.05 + 3.50 + 1.848)\,R2 = 0$$

$$\textbf{Summation of Force} = 0$$

$$R1 + R2 - (166.67\,x\,1.35) - (166.67\,x\,1.65) = 0$$

$$\textbf{Two Equations, Two Unknowns}:$$

$$R1 = 317.006\ g - f$$
$$R2 = 183.003\ g - f$$

$$\textbf{Substituting Values}$$

$$Stress = \frac{317.006\left(\frac{9.81}{1000}\right) N}{(0.57\ mm\ x\ 0.62\ mm) + (0.3\ mm\ x\ 0.21\ mm)}$$

$$Stress = \frac{3.11\ N}{.4164\ mm^2}$$

$$\boxed{Stress = 7.47\ Mpa}$$

APPENDIX A – BRIDGE TOOL STRESS CALCULATIONS

2.3 Bridge Tool Modification

In order to reduce the stress exerted by the clip on the die, contact points were removed. This reduces the direct application of force onto the clip and die. In the illustration shown on figure 7, the auxiliary or support planes were recessed by 0.055 millimeters based from the computation from the stack analysis.

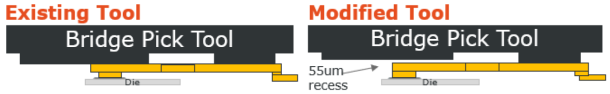

Fig. 7. Comparison of Existing and Modified Bridge Pick Tool

This helps to avoid the floating clip by embedding the clip foot but still leaves room for clip dimple to flex and not brace on the die. Calculating again for the stress on die, it came about 4.03 Megapascal. Refer to Appendix A.

2.3.1 Bridge Tool Evaluation Runs

Simulation runs were done to see the effect of bond force on crack die and tilted clip performance.
Die cracks and short rejects were used as measurement metric in this evaluation.

Table 2. Summary of Existing tool Bond Force Evaluation

Run	Bond Force	Bridge Tool
1	200g	Existing
2	800g	Existing

In line with bridge tool modifications, optimization on the force needed to reduce tilted clip and sway clip rejects; the auxiliary plane was not in contact with the clip anymore. A design of experiment was done in order to determine the optimal bond force and bond speed of clip bonder to reduce both tilted clip and crack die using the modified tool.

Table 3. Summary of Bond Force/Bond Speed Optimization DOE

Run Order	Bond Force	Bond Speed	Bridge Tool
Control	1300	2	Normal
1	1300	1	Modified
2	1300	2	Modified
3	1500	1	Modified
4	1500	2	Modified
5	1000	1	Modified
6	1000	2	Modified
7	800	1	Modified
8	800	2	Modified
9	500	1	Modified
10	500	2	Modified

Another set of evaluation runs compared the existing tool with the current running bond force of the tool with the modified tool with recession using a higher bond force.

Table 4. Summary of Modified Bridge Tool Evaluation

Run	Bond Force	Bond Speed	Bridge Tool
1	400	2	Existing
2	1500	2	Modified

3.0 RESULTS AND DISCUSSION

3.1 Relationship of Bond force, Tilted Clip, and Crack Die

Results from figure 8 show that the force exerted on the die affects both tilted clip and crack die based on the results of the bond force simulation of 200g versus 800g.

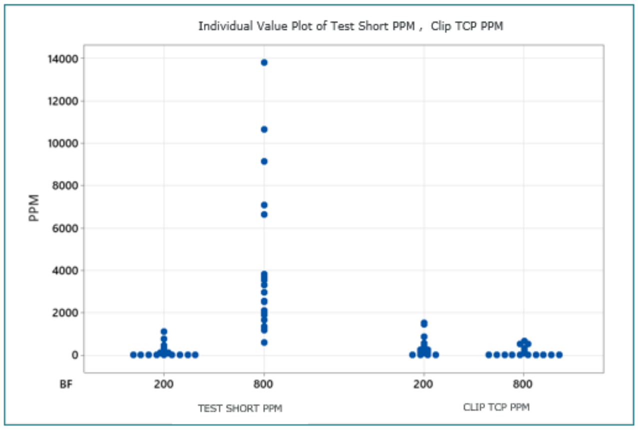

Fig. 8. Relation of bond force to tilted clip and die crack reject PPM

As the bond force increases, the test short ppm also increases. The opposite is true for the tilted clip rejects PPM, as the bond force increases, the PPM decreases. This is mainly because of the possible clearances or gaps shown on the stack analysis. When the force is high, the die is stressed through the dimples causing die crack, but the clip foot sets in properly on the bottom frame, resulting to good clip placement.

3.2 Relationship of Bond force, Bond Speed, and Clip Rejects

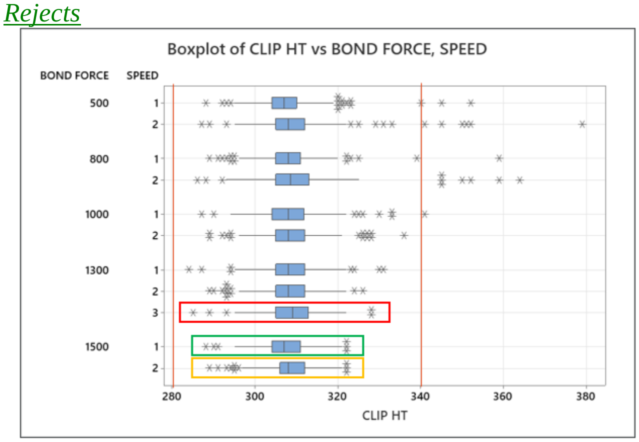

Fig. 9. Relation of bond force, bond speed, and clip height

Finding optimal bond force and speed, as expected, the higher the bond force the lower the reject ppm. Speed setting of 1 and 2 of bonding showed little to no differences in terms of clip rejection. Improvement from current control is a higher bond force of 1300g to 1500g as shown on fig 9.

3.3 Evaluation Results Comparison of Existing and Modified Tool

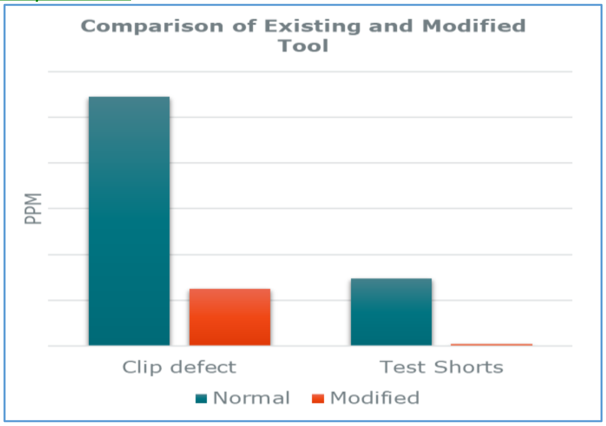

Fig. 10. Comparison of Clip Defect and Test Shorts between Existing and Modified Tool

The third evaluation runs were done with at least 170,000 units for each tool. The comparison of tilted or clip related rejects and test short between the existing tool and modified tool showed an improvement on both the reject PPM. Tilted clip had a 77% decrease while test shorts had a 96% decrease in PPM based on the evaluation as shown on fig 10.

Further modifications of the bridge tool was also made such as making the vacuum supports whole or larger by filling up the gaps illustrated on figure 11. Another round of evaluation was made using 32,000 units per run.

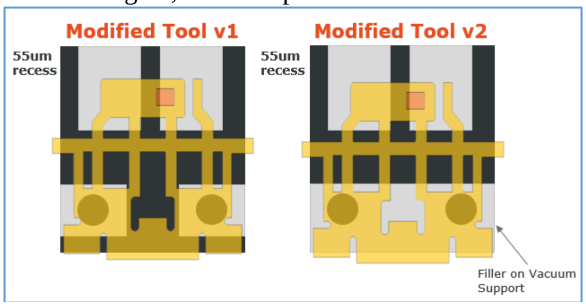

Fig. 11. Comparison between the Modified Tool V1 and V2

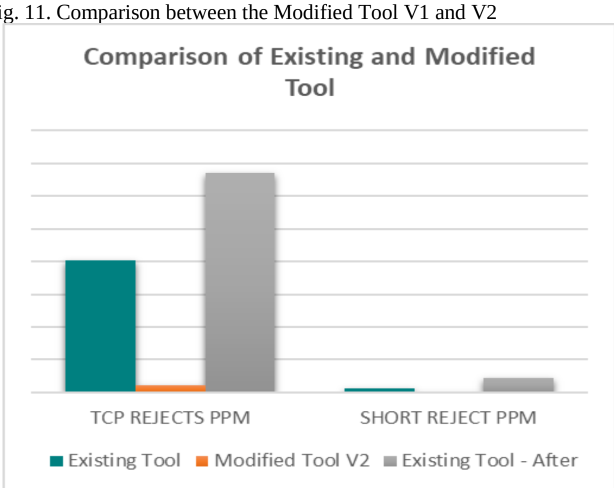

Fig. 12. Comparison between the Modified Tool V1 and Existing

The modified tool also performed better than of the control or existing tool as seen on figure 12, even after the replacement of the existing tool the PPM of the modified tool is still lower. The modified tool only has 228 PPM clip rejects and 0 PPM clip rejects versus the 4644PPM and 105PPM of the existing tool.

4.0 CONCLUSION

Clip bonding can be a cause of crack die due to the possibility of excessive force or stress being applied to the die. Crack signatures due to clip bonding is similar to the customer complaints. The delta between the max stacking height and minimum clip foot within specification is 52um. This causes the clip to tilt causing rejects, if the clip bond force is to be increased, the risk is crack die due to clip dimple bracing on the die. Recessing of the bridge tool auxiliary support by 55um removes the direct stress from applied on the die. The removal of stress on die reduces the possibility of crack while still allowing the bond force to be increase to then address the tilted clip issue. The evaluation data shows that lots using the modified tool effectively reduce the tilted clip and short reject ppm.

5.0 RECOMMENDATIONS

Although the results of the evaluations are promising, need for the modified bridge tool to be subjected to large scale validation using various machines. The tool must also be fabricated for preparation of fan-out. The modification of the tool should also be looked at to be used on other machines (Alphasem/eCLIP Advanced) and packages (SOT1210).

6.0 ACKNOWLEDGMENT

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7.0 REFERENCES

1. Macaspac et al., **Investigation of Silicon Die Crack for Varying Silicon Die Parameters and Die Attach Material**, PHILIPPINE ENGINEERING JOURNAL PEJ 2020; Vol. 41, No. 1, 33-48

8.0 ABOUT THE AUTHORS

HAROLD L. GUTLAY, graduate of Mechanical Engineering in Malayan Colleges Laguna class of 2019 with more than 2 years' experience in Die Attach Process.

JOHN RHYAN R. LLAMAS, hired as Equipment Engineer and now Equipment Manager of FOL DACA and DAWB, 3 years with Nexperia Philippines

9.0 APPENDIX

APPENDIX A – BRIDGE TOOL STRESS CALCULATIONS

Existing Bridge Tool:

$\boldsymbol{Summation\ of\ Moment} = \mathbf{0}$

$$0.625\ R1 - (0.625 + 0.05)(166.67\ x\ 1.35) - (0.625 + 0.05 + 3.50)(166.67\ x\ 1.65) + (0.625 + 0.05 + 3.50 + 1.848)\ R2 = 0$$

$\boldsymbol{Summation\ of\ Force} = \mathbf{0}$

$$R1 + R2 - (166.67\ x\ 1.35) - (166.67\ x\ 1.65) = 0$$

$\boldsymbol{Two\ Equations, Two\ Unknowns}$:

$$R1 = 317.006\ g - f$$
$$R2 = 183.003\ g - f$$

$\boldsymbol{Substituting\ Values}$

$$Stress = \frac{317.006\left(\frac{9.81}{1000}\right) N}{(0.57\ mm\ x\ 0.62\ mm) + (0.3\ mm\ x\ 0.21\ mm)}$$

$$Stress = \frac{3.11\ N}{.4164\ mm^2}$$

$$\boxed{Stress = 7.47\ Mpa}$$

Modified Bridge Tool V1:

$\boldsymbol{Summation\ of\ Moment} = \mathbf{0}$

$$0.625\ R1 - (0.625 + 3.55)(303.03\ x\ 1.65) + (0.625 + 3.55 + 1.848)\ R2 = 0$$

$\boldsymbol{Summation\ of\ Force} = \mathbf{0}$

$$R1 + R2 - (303.03\ x\ 1.65) = 0$$

$\boldsymbol{Two\ Equations, Two\ Unknowns}$:

$$R1 = 171.175\ g - f$$
$$R2 = 328.825\ g - f$$

$\boldsymbol{Substituting\ Values}$

$$Stress = \frac{171.175\left(\frac{9.81}{1000}\right) N}{(0.57\ mm\ x\ 0.62\ mm) + (0.3\ mm\ x\ 0.21\ mm)}$$

$$Stress = \frac{1.68\ N}{.4164\ mm^2}$$

$$\boxed{Stress = 4.03\ Mpa}$$

Modified Bridge Tool V2:

$\boldsymbol{Summation\ of\ Moment} = \mathbf{0}$ R1

$$0.625\ R1 - (0.625 + 4.298)(303.03\ x\ 1.65) + (0.625 + 4.298 + 1.11)\ R2 = 0$$

$\boldsymbol{Summation\ of\ Force} = \mathbf{0}$

$$R1 + R2 - (303.03\ x\ 1.65) = 0$$

$\boldsymbol{Two\ Equations, Two\ Unknowns}$:

$$R1 = 102.625\ g - f$$
$$R2 = 397.374\ g - f$$

$\boldsymbol{Substituting\ Values}$

$$Stress = \frac{102.625\left(\frac{9.81}{1000}\right) N}{(0.57\ mm\ x\ 0.62\ mm) + (0.3\ mm\ x\ 0.21\ mm)}$$

$$Stress = \frac{1.006\ N}{.4164\ mm^2}$$

$$\boxed{Stress = 2.42\ Mpa}$$