Journal of Engineering Research and Reports

20(2): 45-58, 2021; Article no.JERR.64234
ISSN: 2582-2926

"Rey Resin Dispense Pattern" A Solution to Package Voids Defect on Thinner Package Thickness in Compression Mold

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Authors' contributions

This work was carried out in collaboration between both authors. Author LJTB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors RNCA managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JERR/2021/v20i217264
Editor(s):
(1) Dr. Guang Yih Sheu, Chang-Jung Christian University, Taiwan.
Reviewers:
(1) Neha Munjal, Lovely Professional University, India.
(2) Ayyob Asadbeigi, Islamic Azad University, Iran.
(3) Suman De, SAP Labs India Pvt. Ltd, India.
Complete Peer review History: http://www.sdiarticle4.com/review-history/64234

Original Research Article

Received 10 November 2020
Accepted 14 January 2021
Published 09 February 2021

ABSTRACT

This paper will discuss how package voids Mold defect was addressed on thinner Compression mold packages like BGA (Ball Grid Array) and Sensor Devices. Significant action was the application of "Rey Resin Dispense" pattern in compression mold granule compound dispensing was a key action in reducing package voids defect. Using a DMAIC methodology (Define, Measure, Analyze, Improve and Control), a powerful analytical tool that serves as a guide towards the success of eliminating package voids defect. Using this methodology, all Key Process Input Variables (KPIVs) of compression mold and its molding compound material were identified as X's or potential causes and test its significance to affect Y-response which is the package voids. Funneling of X's further trimmed to the most possible contributor to package voids. The remaining possible contributor X's undergo statistical validation which point to granule compound resin dispensing as the main contributor to induce package voids defect. Several actions were tried but failed to zero-out the defect. With the help of brainstorming and imaginative ideas and data gathered on how to improve granule resin dispense of compression mold positive outcome was

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realized. From the concept of light ray, to naming it as “Rey Resin Dispense” significantly reduce package voids defect in all thin BGA and Sensor devices. This learning was then applied to all existing thin packages and to new packages in compression molding process.

Keywords: Rey resin; compression mold; resin dispense; compound; granules dispense.

1. INTRODUCTION

Technology has revolutionized our world and daily lives. For example, from wired phone to smartphone cutting the cord and utilizes digital wireless technology connecting various potentials around the world [1,2]. The Smartphone technology is getting more compact to its handiest usage and size but packed with a powerful capability. Inside that smartphone product are the small IC’s (Integrated Circuits) and other components working together to be able to provide powerful usage to the user [3,4]. These IC devices are getting smaller and thinner to provide enough slot for other components to fit inside the limited space. One of those products are the BGA which support the touch technology of the screen, and the Sensor device focused on X, Y and Z-axis for phone orientation. Refer to Fig. 1.

There are several processes involved to assemble BGA/Sensor packages, and one of the major focus is at Molding as illustrated on Fig. 2.

From Molding process, there are two types of technology. Both Transfer Mold and the Compression Mold having the same purpose: encapsulating wire bonded IC’s to protect from external forces as shown on Fig. 3.

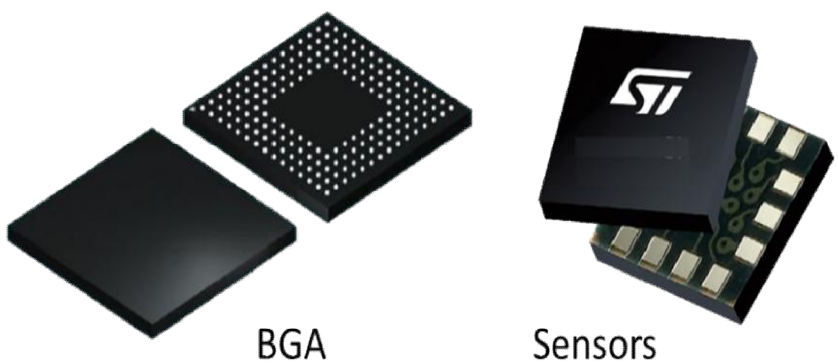


Fig. 1. Example image of single unit BGA and Sensors

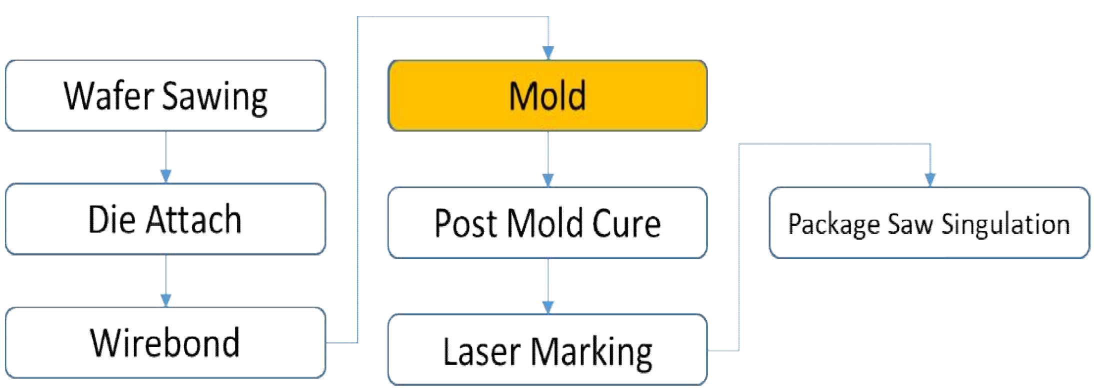


Fig. 2. Assembly major processes

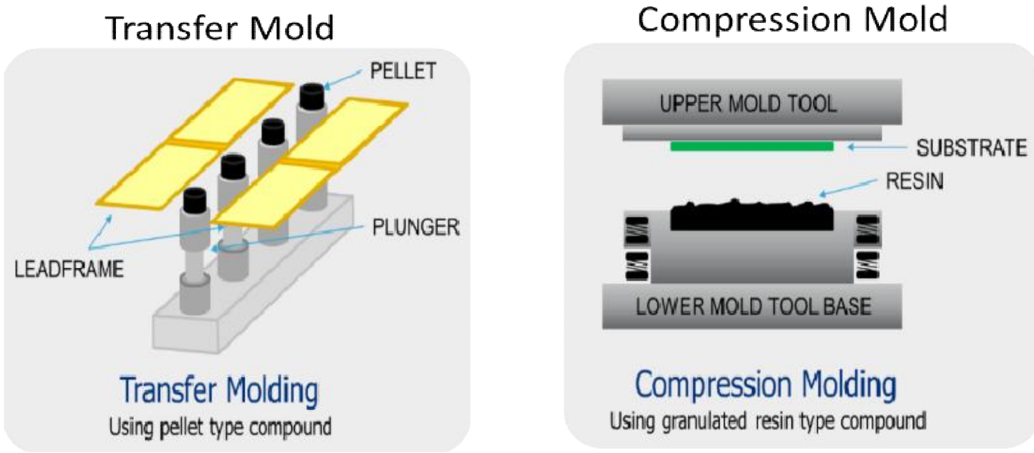


Fig. 3. 2-Types of molding technology

Fig. 4. Granule/Resin compound of compression mold comparing to pellet/ tablet of transfer mold

1.1 Compression Molding

The advance technology in molding IC devices uses granule compound instead of conventional pellet or tablet molding compound. The method of loading the granule compound is through "Dispensing". Then cavity moves up to compress the melted granule compound to form a molded package [5,6,7].

Compression mold advantage has the capability to handle large density of strips where all individual device or unit seats in the strip, which carries units [8,9]. It is also capable in molding long wire span at lesser flow of melted molding compound even on thinner packages thickness. (Fig. 5)

With this high capability, all complex and critical packages like BGA/Sensors were allocated to compression machine to maximize its large strip density potential and good quality outcome.

2. PROBLEM IDENTIFICATION AND TECHNICAL ANALYSIS

2.1 Problem Identification

As the technology requirement is getting more and more complex, the new BGA/Sensor package version needing thinnest package requirement amongst the existing packages refer to Fig. 6.

On Fig 6.1 shows that new BGA/Sensor quality performance at Mold is not good in terms of specific package voids It is more than a thousand times higher compared with the existing packages.

Package void is a defect induce during molding process describe as a hollow portion of the molded package [10]. On case of BGA/Sensor, manifestation seems inherent on every mold shot and localized within the strip. (Fig. 7)

With this, the problem statement is:

High rejection rate of package voids defect on new BGA/Sensor devices which affect yield performance of molding process.

So the objective is to reduce drastically package voids PPM for new BGA/Sensor to be comparable to existing packages.

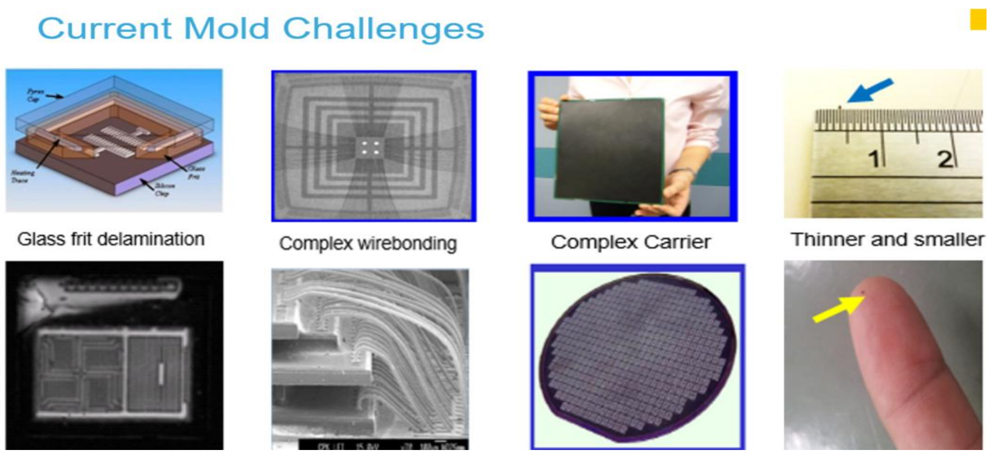


Fig. 5. Compression mold capability to process complex packages

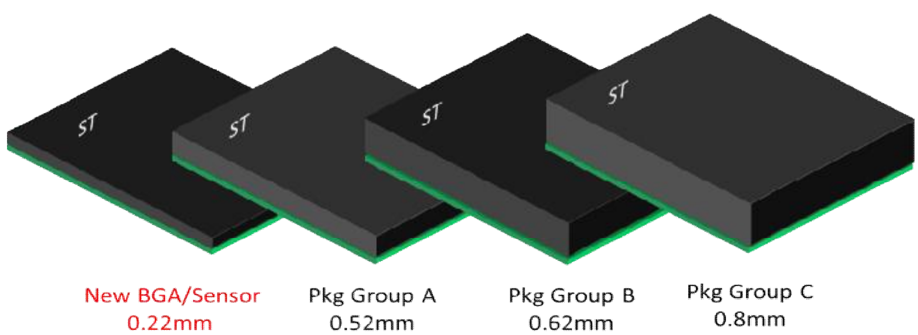


Fig. 6. Comparing new BGA/Sensor in all existing pkgs in terms on pkg thickness

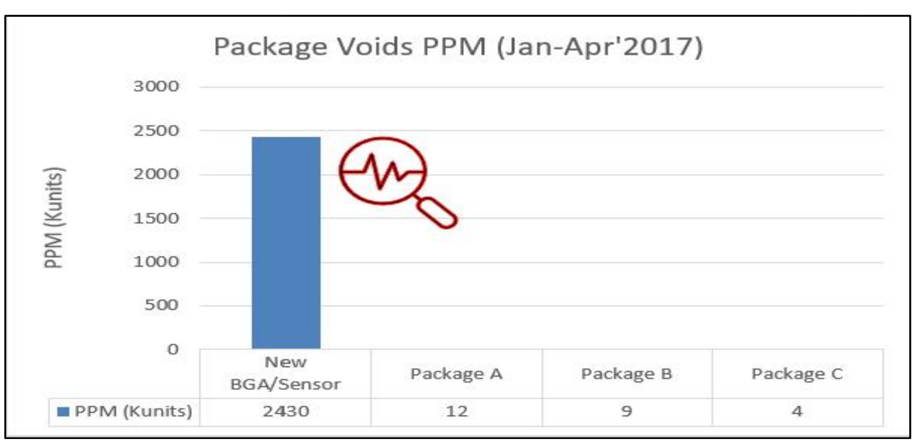


Fig 6.1. Actual image of package voids within the strip

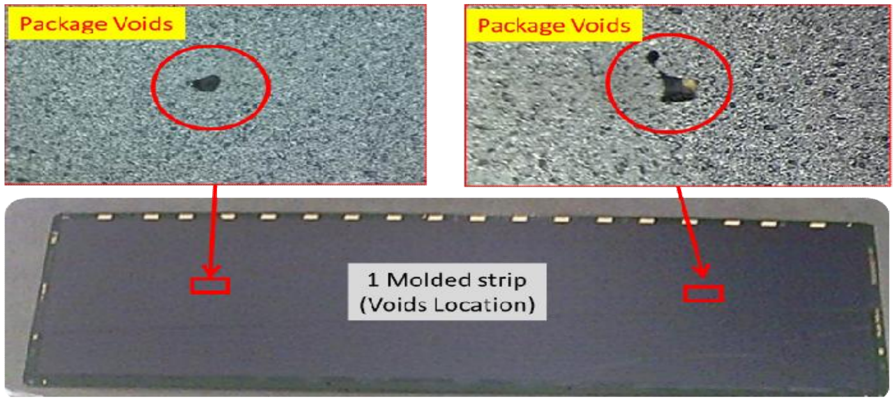


Fig. 7. Actual image of package voids within the strip

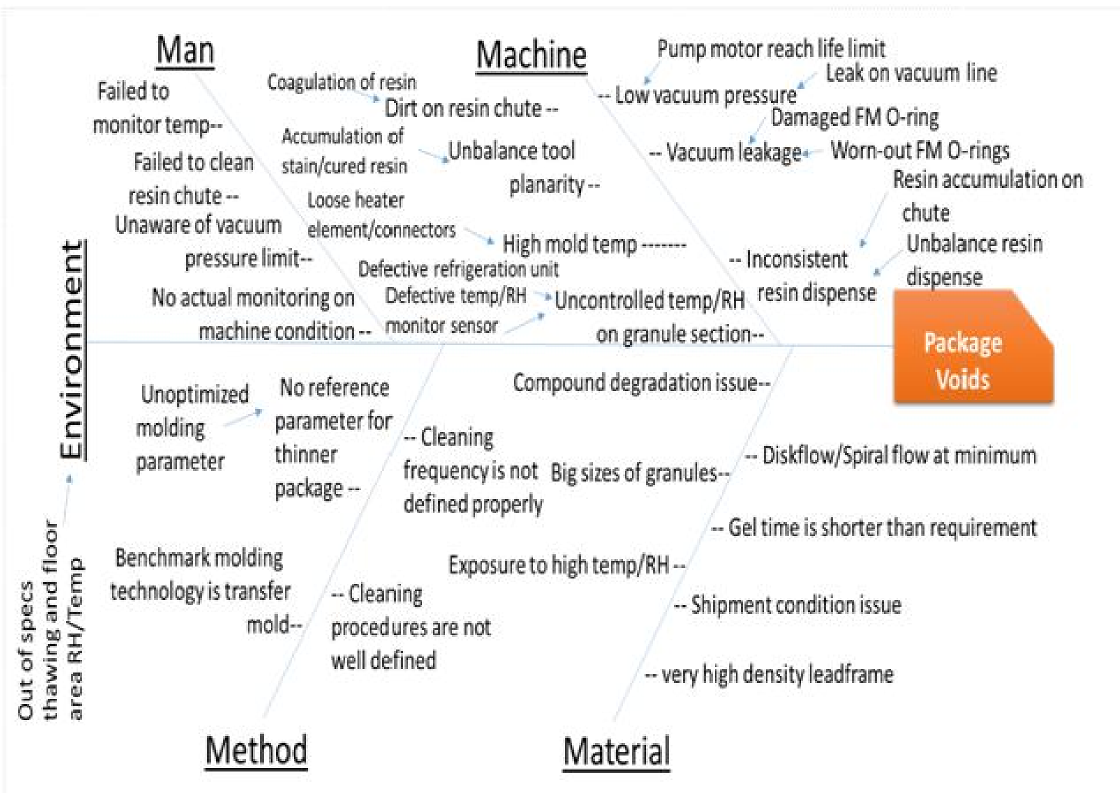


Fig. 8. Fishbone diagram of different potential causes or X's

2.2 Identifying and Analyzing Potential Rootcauses

From the detailed process step mapping, analysis of X's was started through the use of fishbone diagram (refer to Fig. 8.) Man, Machine, Method, Material and even the Environment were assessed. There is a total of 24 X's or potential root causes identified which needs further validation.

From the fishbone diagram, all identified X's which probably could induce package voids defect were validated using a cause and effect matrix, refer to Table 1.

From the 23 X's identified and validated, 3 most potential causes were identified to induce package voids. These 3 potential causes are somewhat related to the flow ability of the molding compound as shown on Table 2.

Table 1. Cause and effect matrix for validating X's

Potential Causes	Method of Validation	Validation Result
Failed to monitor temp	Get actual mold temperature when encountered package voids	All temperature points are within the temp range requirement
Failed to clean resin chute	Check resin chute when the mold shot is with evident of package voids	No dirt accumulation on resin chute
Unaware of vacuum pressure limit	Ask optr if aware of the pressure limit and check actual limit setting	Optr is aware of the limit and pressure limit is properly set on the machine
No actual monitoring on machine condition	Check optr and tech checklist and individually validate to the actual machine condition	All check items are within the machine condition requirement
Coagulation of resin	Check actual granules condition and temp/RH readings	No coagolation on granules and temp/RH are within the specs
Accumulation of stain/cured resin	Check actual molding on affected strips for unbalance planarity during clamping	All bleed out within the strip is balance with no signs of unbalance to clamping
Loose heater element/connectors	Check actual temparature	All temperature are within the specification
Defective refrigeration unit	Test actual refrigerant unit and tally with actual reading	Temperature readings are tallied with actual sensor read-out
Defective temp/RH monitor sensor	Check and test Temp/RH monitor for defectiveness	Monitor is working fine and actual readings are still considered accurate
Pump motor reach life limit	Check working hour of pump motor	Pump motor still within the working hour of 2,400H which max is 8k.
Leak on vacuum line	Individually check vacuum line connectors and fittins for possible pressure leakage	NO leakage observed on the lines
Damaged FM O-ring	Check actual condition of FM O-rings	No damaged found
Worn-out FM O-rings	Check actual condition of FM O-rings	Not yet worn-out and still within the 3months life period
Resin accumulation due to wearing of stainless surface	Check resin chute when the mold shot is with evident of package voids	No dirt accumulation on resin chute
Unoptimized molding parameter	Check actual parameters	Evident of incomplete filling that resulted to voids which can be link to parameter combination problem
Benchmark molding technology is transfer mold	Check qualification report of Development group and running pkg in Calamba for compression mold	There is a reference package running in compression mold which is MEMS
Cleaning frequency is not defined properly	Check process specification	Cleaning frequency is well defined
Cleaning procedures are not well defined	Check process specification	Cleaning procedure is well defined
Compound degradation issue	Check actual floorlife and shelflife of compound that is inducing package voids	NO issue with the compound handling that will cause degradation on its characteristics
Big sizes of granules	Check actual granule size which can cause the unfilled package	With the thinner package thickness, a possible granule size is not match with a finer volume requirement
Exposure to high temp/RH	Check actual Temp and RH on granules area	All actual temp/RH are within the specification
Diskflow/Spiral flow at minimum	Check CoC and Other packages performance in terms on voids	CoC readings are within the specification and a very minimal voids for other pkgs utilizing compression mold
Gel time is shorter than requirement	Check CoC and Other packages performance in terms on voids	CoC readings are within the specification and a very minimal voids for other pkgs utilizing compression mold mold
Unbalance granule/resin dispense	Visual check actual granule/resin Dispense distribution	Huge gap in between granule On some areas

Table 2. 3 Most potential rootcauses

Potential Root causes	Possible or not possible cause	Controllability
1. Un-optimized molding parameter	Possible cause	Controllable
2. Big Sizes of granule/resin	Possible cause	Controllable
3. Unbalance granule/resin dispense	Possible cause	Controllable

2.3 Validation of Most Potential Rootcauses

1st Un-optimized molding parameter. DOE (Design of Experiment) has been made to check whether the mold parameter combination will have a significant effect to the occurrence of package voids.

Result of DOE (Table 3) revealed that mold parameter combination did not reduce package voids occurrence. And statistical test (Fig. 9) proved that there is no significant difference versus existing parameter. Therefore, mold parameter is not directly inducing package voids defect.

2nd is the Big size granule. The bigger the size the more gaps inbetween granules can be observed. Below fig (Fig. 9.1) is the actual granule measurement of the existing compound.

The material sample requested from compound supplier and tried finer granule size (Fig. 9.2) if the hypothesis is correct to distribute more granules to fill those gaps in between granules.

Table 3. Design of experiment on different parameter combination

Condition	Compress pressure	Compress time	Result
Leg 1 --	15	8	Failed w/ voids
Leg 2 -0	15	13	Failed w/ voids
Leg 3 -+	15	18	Failed w/ voids
Leg 4 0-	18	8	Failed w/ voids
Leg 5 00	18	13	Failed w/ voids
Leg 6 0+	18	18	Failed w/ voids
Leg 7 +-	20	8	Failed w/ voids
Leg 8 +0	20	13	Failed w/ voids

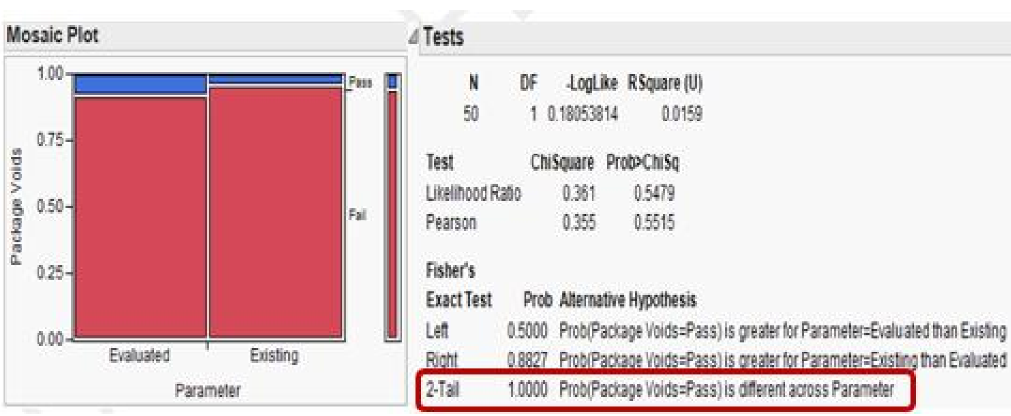


Fig. 9. 2-Proportion test if evaluated parameter has significance

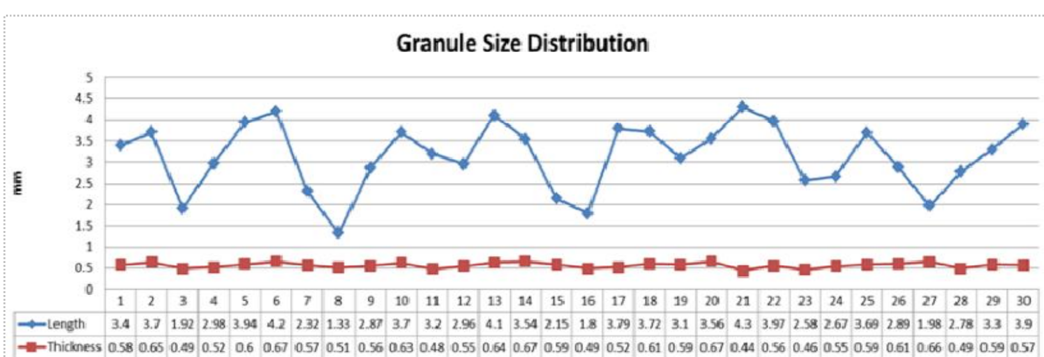


Fig. 9.1. Granule/resin size of existing compound

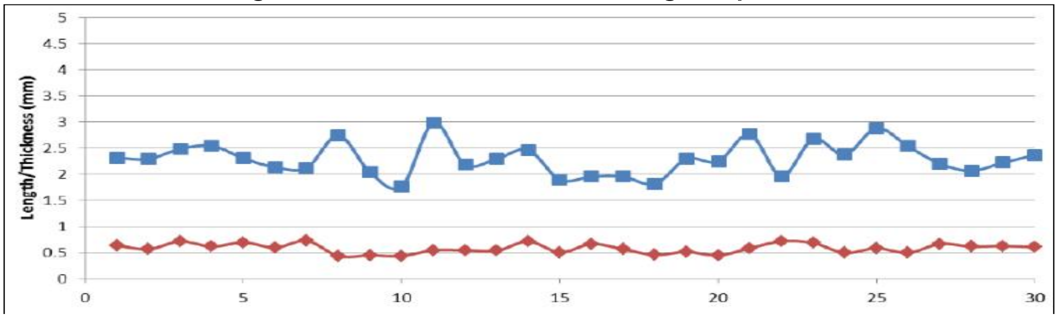


Fig. 9.2. Actual measurement of new granule size sample from supplier

Validation resulted to no effect to close the gap in between granule as package voids still manifest every mold shot as shown on Fig. 10.

Statistical test proves that bigger versus finer granule has no significant difference to package voids occurrence. (Fig. 11).

Therefore, the existing range of mold parameter has no effect on package voids, additionally, finer granule size has not even reduced the defect occurrence. The derived data and initial validation results revealed a more interesting part of the analysis which point to the 3rd potential root cause.

3rd Uneven granule/resin dispense. Revisiting the initial result of investigation, it seems high occurrence of package voids happen on thin package while for thicker packages it is manageably low. With this, further comparing of resin weight and its distribution appearance during dispensing was done.

The Resin/granule weight of new BGA/Sensor is half of the Package A weight which is due to its thin package thickness requirement as shown on Table 4.

The weight difference has a significant visual appearance on the granule/resin carrier into the machine (Fig. 12). There is an obvious gap between granules on the BGA/Sensor while zero gap between granules for other Packages as shown. This evidence led again to an actual validation if the gap in between granule will close during molding. A series of gap simulation has been executed to further understand and validate its failure mechanism.

Upon actual simulation and validation, this huge gap in-between granule/resin when applied with mold heat of 180°C ±5°C could not close fully leaving a hole and creating a package void. With this, package voids induced by the huge gap between granules prior to forming a package as shown on Fig. 13.

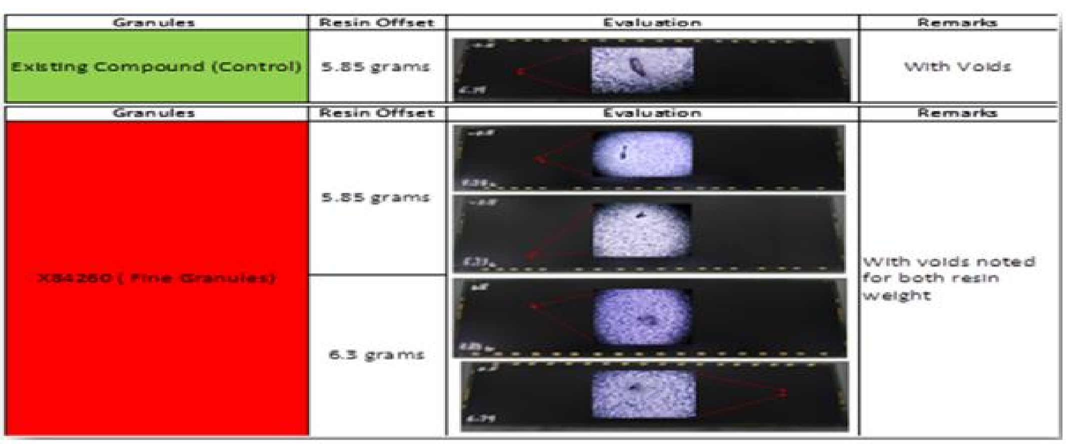


Fig. 10. Actual result of trials of finer granule size

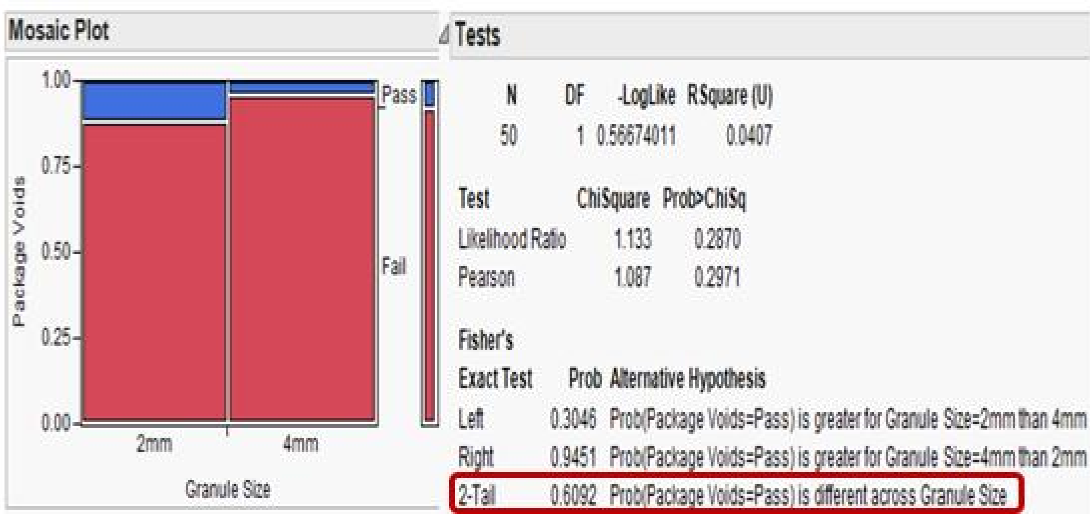
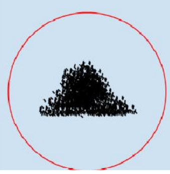


Fig. 11. 2-Proportion test if finer granule size has significance

Table 4. Granule/Resin weight comparison per package

Package	New BGA/Sensor	Package A	Package B	Package C
Total Package thickness	0.22mm	0.52mm	0.62mm	0.8mm
Resin Weight	~5.85 grams	~10.4 grams	~15.25 grams	~19.85 grams
Resin volume visual comparison				

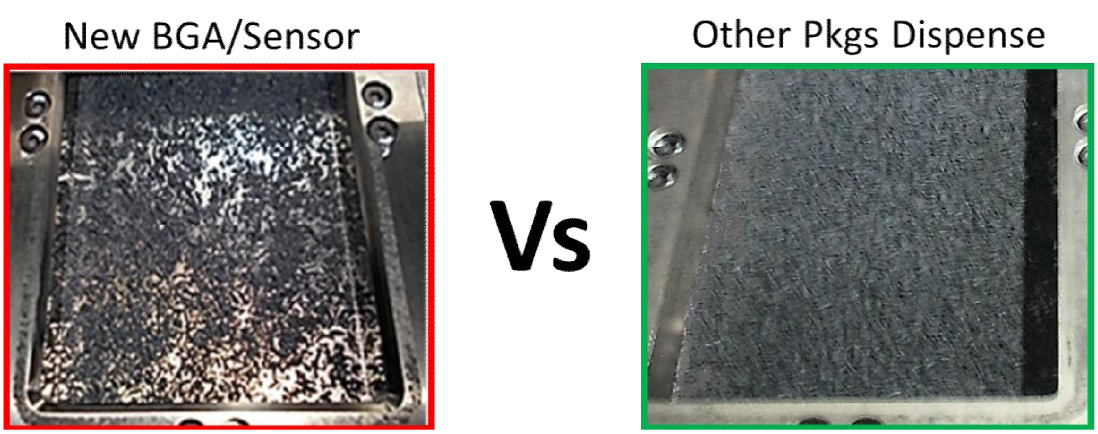


Fig. 12. Granule/resin dispense actual appearance on the effect of weight difference

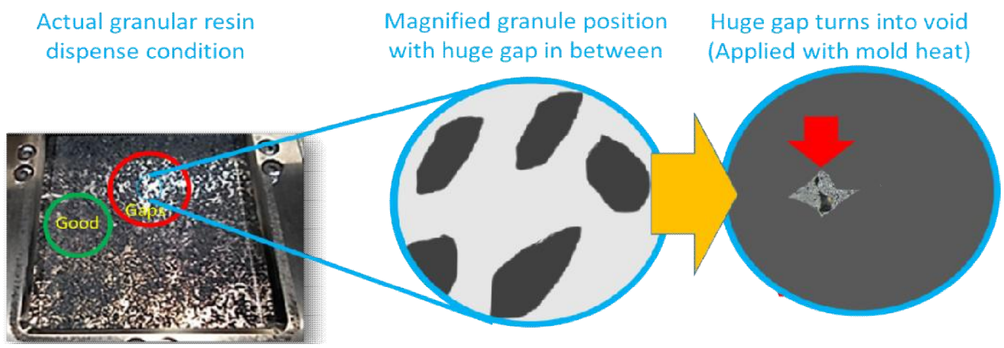


Fig. 13. Illustration on how package voids occur when there is a huge gap in between granules

Table 5. Selection of best alternative solution

TRUE cause	EP level	Alternative solutiozn	Validation	
			Method	Result
Un-even granule/ resin dispense	1	Slower granule/resin dispense by 50% from existing setting	Set speed 50% reduction	Still with huge gap in between granule/resin
	1	Add dispense lines from 4 to 8 lines	Set 8lines dispense pattern	Still with huge gap in between granule/resin
	1	Focus the dispense on both outer area	More dispense to the outer	Trapped air which worsen voids occurrence
	1	Dispense focus to the middle (Rey Resin Dispense Pattern"	More dispense on the middle	Zero package voids

This phenomenon (Fig. 13) is the weakness of packages with lower package thickness requirement. The lesser the granule requirement, the more susceptible it is to have a huge gap between granules which will then lead to package voids defect.

Therefore, the un-even granule/resin dispense due to low granule weight requirement of package is the TRUE ROOTCAUSE.

3. SOLUTION FORMULATION AND IDENTIFICATION OF BEST SOLUTION

3.1 Selection of Best Alternative Solution

Several alternative actions were laid down to assess and validate total effectiveness to address package voids.

3.2 Review of Related Work

3.2.1 How was the action name derived?

The concept of "light ray" where the focus of light is on the middle and some distorted rays going farther from the middle as shown on Fig. 14.

To distinguish the uniqueness of the new dispense pattern, it is named after the author "Rey" who think this concept will help address the problem and it's called "Rey Resin Dispense Pattern".

It is the same as the improved resin dispense or Rey Resin Dispense which focus on the middle and some part of granules were scattered away from the center (Fig. 15).

The Rey resin dispense pattern simply negate all gaps in between granules but instead focus the dispense to on the center. An illustration to compare the effect of huge gap in between granule versus the granules focus on the middle which zero voids occurrence (Fig. 16).

3.3 Validation of Best Solution

Statistical Validation (Fig. 17) on the effectiveness of "Rey Resin Dispense Pattern" in terms on package voids defect occurrence has a significant difference to the existing dispense pattern with consistent Zero Voids occurrence.

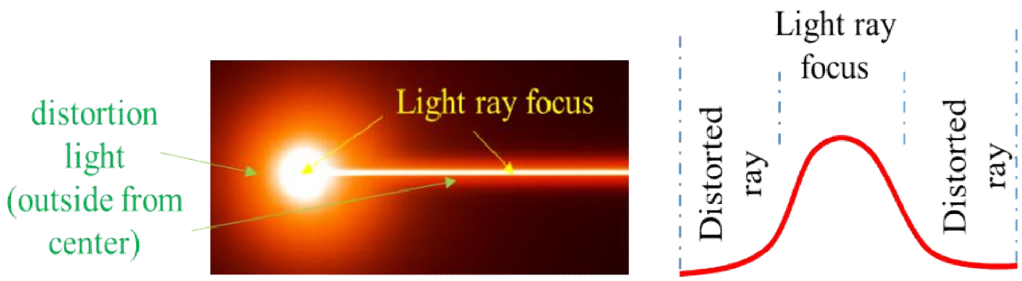


Fig. 14. Light Ray reference in naming the dispense pattern

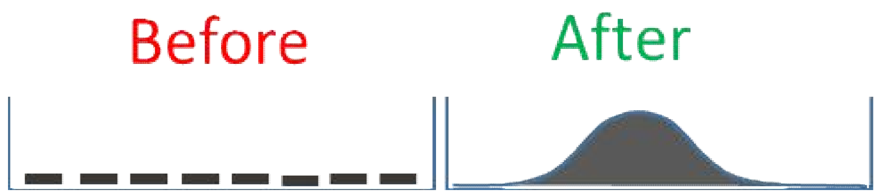


Fig. 15. Comparison of previous and new rey resin dispense

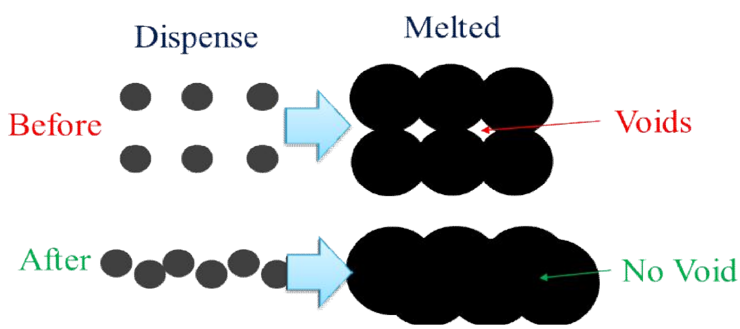


Fig. 16. Illustration comparison between the standard resin dispense versus the new resin dispense and the effect to package voids occurrence

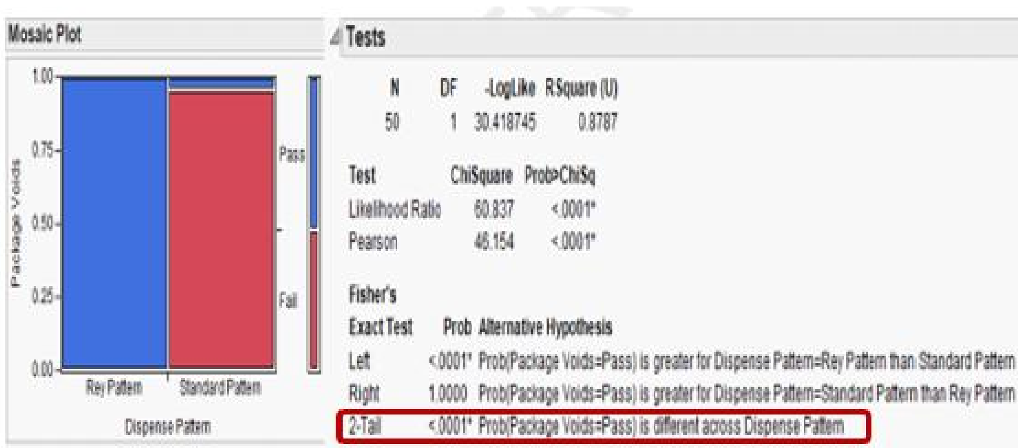


Fig. 17. 2-Proportion test for rey resin dispense pattern vs standard pattern

Table 6. Implementation of best solution and continuous monitoring and fan-out

Failure Mode	Validated KPIV/Cause	Permanent Action	Resp/ Completion Date	Status
Package Voids	Unbalance resin dispense pattern	Implement Rey Resin Dispense pattern	Lester Belalo Nov 2017	Closed
		Monitor performance of new BGA/Sensors	Nov 2017 to December 2019	Closed
		Fan-out improvement action to other new packages	Q3 2018	Closed
			Q2 2019	Closed

3.4 Implementation of Best Solution

Prior to implement the new dispense pattern, a potential problem analysis was made, and counter preventive measures were implemented (PPA) to prevent any problem may arise during the implementation. Refer to Table 6.

4. RESULTS AND IMPACT

After the implementation, package void PPM were reduced significantly in Assembly manufacturing (Fig 17.1) from a thousand PPM.

The elimination of package voids (Fig 17.2) has an effect also on other processes like the final auto vision inspection where the voids also part of monitoring. The fig shows the same significant drop in PPM on voids. With the consistent zero defect plus a strong quality and process control at molding process, auto vision inspection steps were reduced from 6 sides inspection to 4 sides inspection.

Unit cost was also reduced by a fraction as other auto vision steps were eliminated.

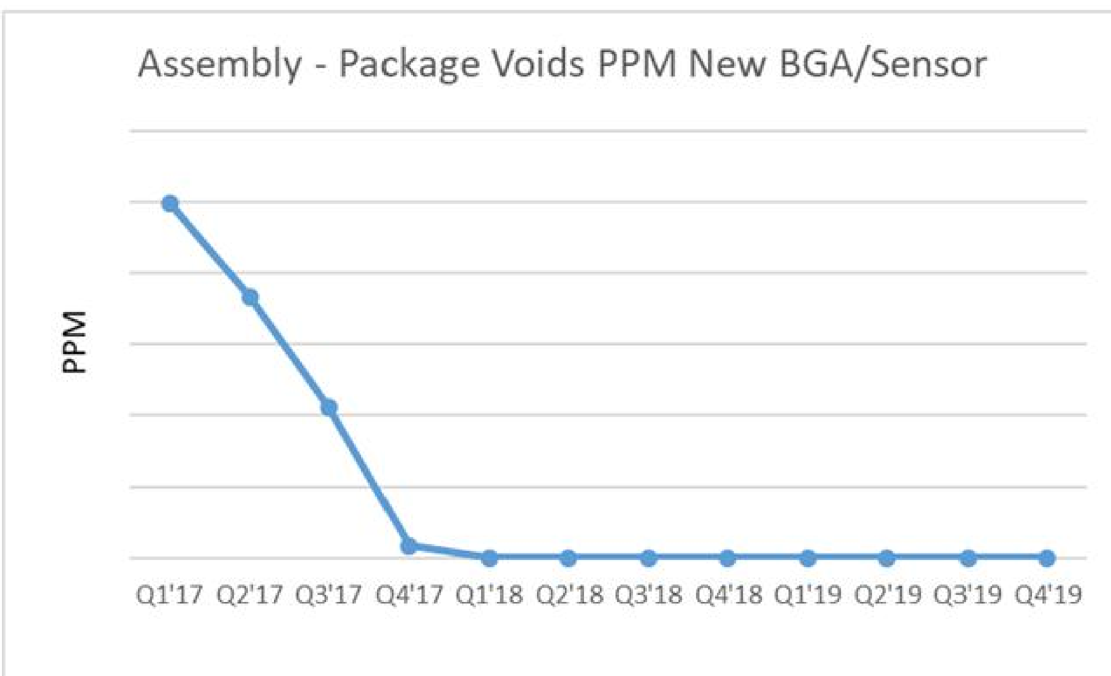


Fig. 17.1. Assembly package voids PPM performance drops to Zero

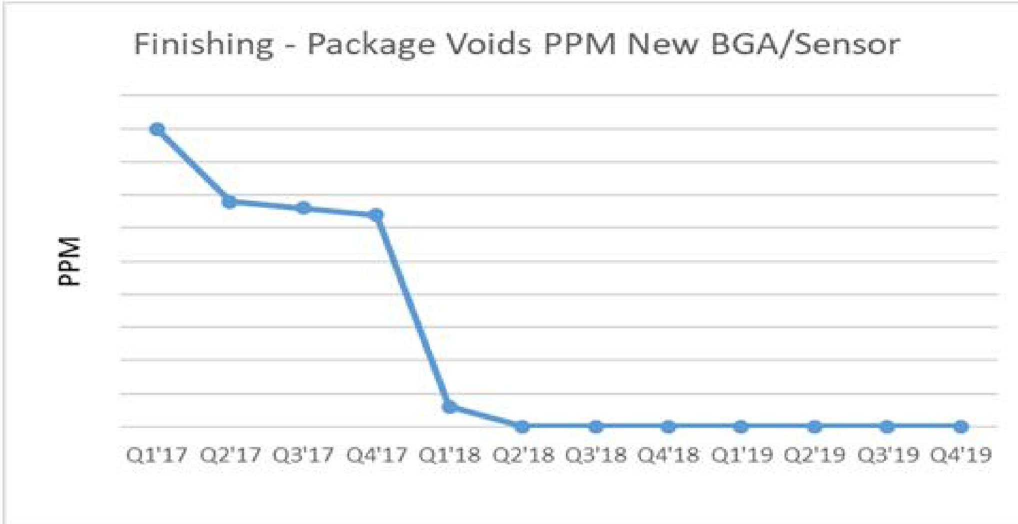


Fig. 17.2. Finish package voids PPM performance drops to Zero

5. CONCLUSION

A correct use of problem-solving methodology could help understand each input variables of the process and its effect to the identified problem. Data made the analysis easier and eventually point to the true root cause.

For the solution of package voids, learnings are new. One must be creative in understanding the data.

Rey Resin Dispense pattern is the key action that eliminated package voids with huge impact not only on molding process, but also for the Finishing process, furthermore it has simplified the inspection steps.

6. RECOMMENDATION

The study abled us to understand the limitation of standard dispensing which is not applicable for thin package, while the Rey Resin Dispense pattern also is not applicable for thicker package thickness as if will overflow on the basin or cavity. With this, any package thickness less than 0.3mm can use Rey resin dispense, while for more than 0.3mm thickness, a standard resin dispense is applicable. It should be applied not only to the existing packages but also to other incoming packages.

DISCLAIMER

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 personal efforts of the authors.

ACKNOWLEDGEMENT

The authors would like to acknowledge the contribution of the team, especially from STMicroelectronics Top Management down to the operators in supporting the drive to improve the quality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/64234