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LFBGA273 Die Crack Reduction through Mold Process Improvement

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Abstract— *In the changing package portfolio of ST Calamba from a major HVQFN plant to a BGA plant, one of the most complex and highest volume package lead type was LFBGA273. This was successfully transferred and qualified to our site but during the large scale volume production it encountered a major quality excursion which is die crack detected at test but was pinpointed to be encountered at mold process.*

This technical paper will be utilizing DMAIC as the strategy in solving this problem. With a very extensive defect analysis to define the failure mechanism and sound simulation to replicate problem lead to concrete actions such as mold cleaning process enhancement and input variable controls to significantly reduce die crack occurrence from reaching test and permanently addressing sources at assembly.

Keywords— *BGA Die Crack.*

I. Introduction

From 2006 to 2009 ST Calamba is a HVQFN factory with few BGA packages. Starting Q2 2009, we were transferring HVQFN to other plants while Q4 2009 of the same year we are transferring BGA packages from other plants to Calamba wherein we shifted to a 60% BGA in terms of value and more complex design. In a matter of three quarters Calamba has become a major BGA factory.

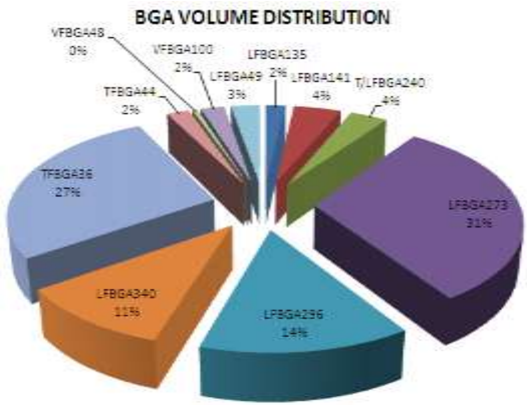

Fig. 1. BGA volume distribution pie chart

LFBGA273 is our highest volume BGA package as of Q1 2010 which accounts to 31% of the total BGA volume. It is a substrate based 10 x 10 package size with single die construction. It is among the largest and thinnest die and it has the smallest die to package ratio among 10x10 packages.

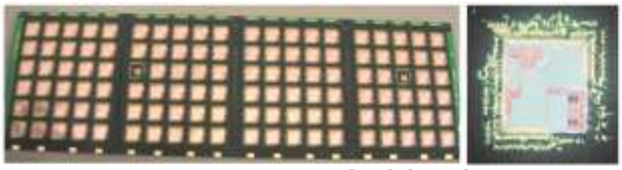

Fig. 2. LFBGA273 wire bonded sample

Table 1. BGA package construction matrix

Package	Die	Die Thickness	Die Size (mm)	Package Size(mm)	Die to Pkg Ratio
LFBGA135	Die1	150	2.705 x 2.44	7 x 7	7.4240175
	Die2	250	2.14x0.85		
	Die3	150	1.56 x 1.463		
	Die4		3.06 x 2.89		
LFBGA141	Die1	150	3.82 x 3.04	7 x 7	4.219482
	Die2	250	2.14x0.85		
	Die3	150	1.85 x 2.75		
	Die4		3.06 x 2.89		
LFBGA240	Die1	280	5.582 x 5.582	10 x 10	3.209374
LFBGA340	Die1	150	[illegible]	12 x 12	3.266261
	Die2		2.43 x 3.37		
TFBGA240	Die1	150	5.58 x 5.58	8 x 8	2.0554721
VFBGA48	Die1	120	2.660 x 2.146	4 x 4	2.8029066
TFBGA88	Die1	250	3.887 x 4.481	7 x 7	2.8132389
LFBGA49	Die1	150	2.7064 x 2.4388	4 x 4	2.4250032
	Die2		1.61 x 0.98		
LFBGA273	Die1	150	[illegible]	10 x 10	3.0683006
LFBGA296	Die1	150	5.150 x 5.416	10 x 10	3.585206
	Die2		3.350 x 2.410		

1.1 Design Phase

1.1.1 LFBGA273 die crack performance at test

As per LFBGA273 TN362 and TN500 rejection trend increased starting Feb'2010. Note that TN362 and TN500 are test bins for die crack.

Fig. 3. LFBGA273 Die crack rejection rate at Test

1.1.2 LFBGA273 lot rejection trend

This increase of reject rate translate to increase no. of lots affected by die crack which reached a high of 31 lots last ww1009 as shown in figure 5.

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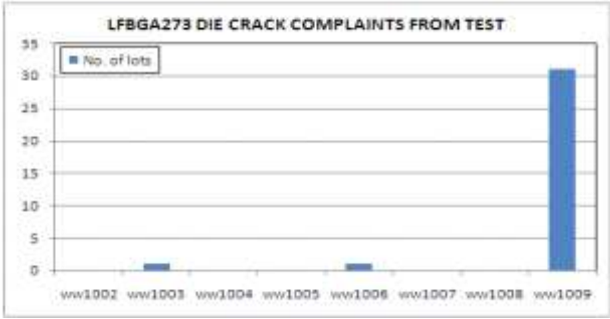


Fig. 4. LFBGA273 Die crack No. of lots trend

1.2 *Map and Measure Phase*

1.2.1 *Defect phenomenon*

Based from the failure analysis of lots with high %OS, open-short, at test. it was confirmed that TN362 and TN500 rejects was due to die crack as shown in the figure 5.

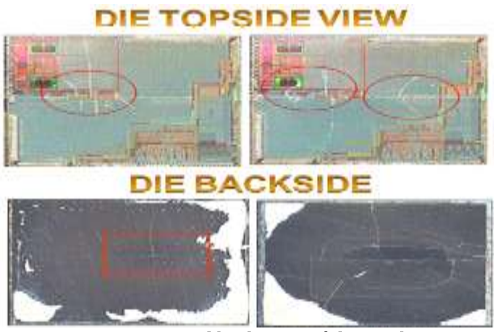


Fig. 5. Top and back view of die crack

1.2.2 *Defect characterization*

Optical inspection showed package dent and substrate crack as indicated by the green arrows. Cross section analysis revealed that the substrate crack propagates to the mold compound surface up to the solder pad as indicated by the red arrows. The location of die crack (blue box) coincides to the location of the substrate crack (green box).

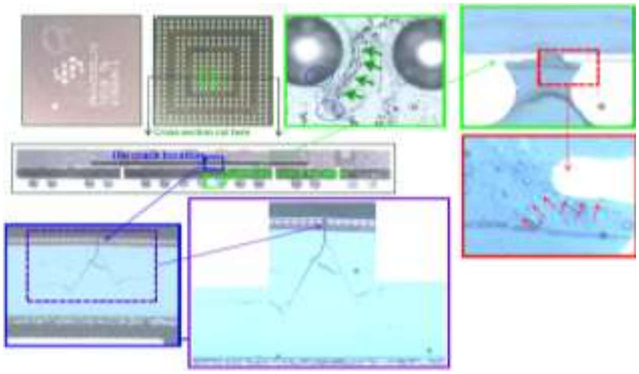


Fig. 6. Die crack high magnification and cross section analysis

1.2.3 *Substrate dent mapping*

As per mapping all unit with die crack has dents at different location of the unit

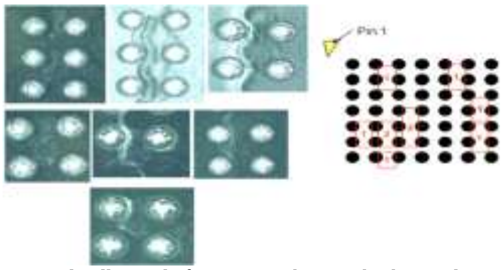


Fig. 7. Actual cull sample for onemap that was broken at degate area

II. Experimental Section

2.1 *Analyze Phase*

2.1.1 *Failure mechanism*

Based from the defect signature possible cause of die crack is protrusion on the surface where unit is substrate is placed with opposing force coming from the top resulting to fulcrum effect.

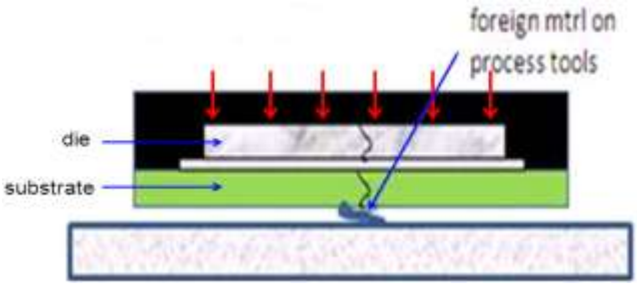
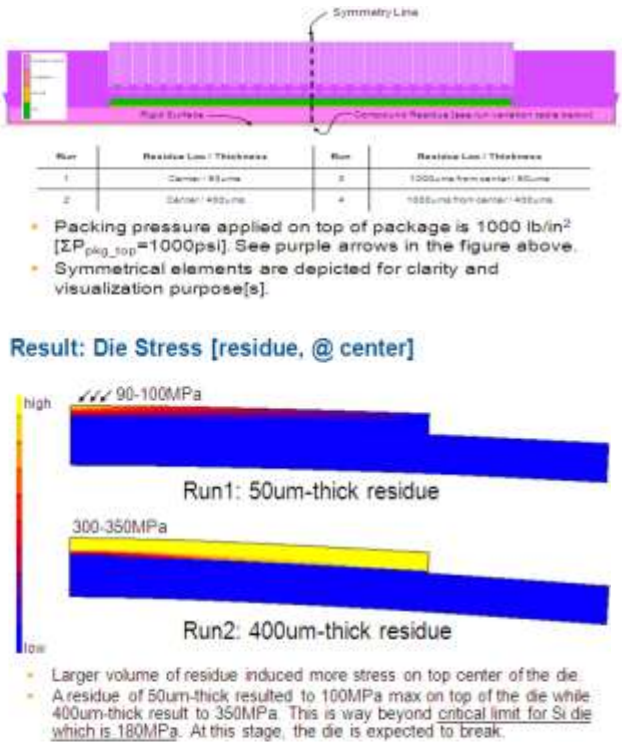


Fig. 8. Illustration on potential failure mechanism

2.1.2 *Finite element analysis*

From the potential mode a finite element modeling was done to check the die stress level of varying debris size and the location under the unit to assess for die crack.



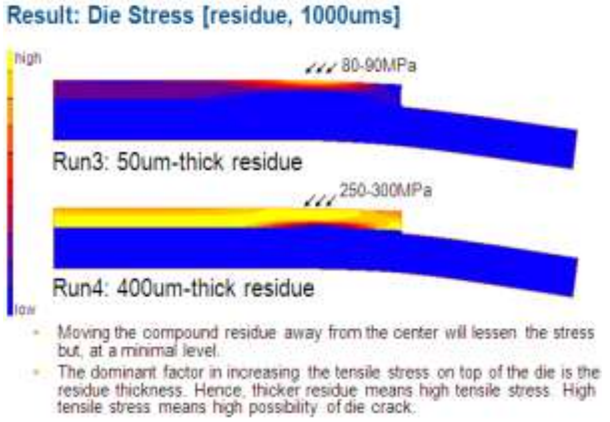


Fig. 9. Finite element analysis modeling for die crack

Compound residue size [thickness] is the dominant factor in increasing the die stress. High die stress means high possibility of die crack. Moving away the compound residue will lessen the die stress but, at a very minimal effect.

Even at 50-um residue thickness, the stress magnitude has already reached 100MPa and increased to 350MPa with a 400um residue. Note that critical limit for silicon die is 180MPa. Which means that it [residue] can accumulate to a higher volume anytime, if not being cleaned.

2.1.3 *Process mapping of LFBGA273*

Conducted process mapping per log point for die crack and results revealed that die crack is seen after mold process via SCAT.

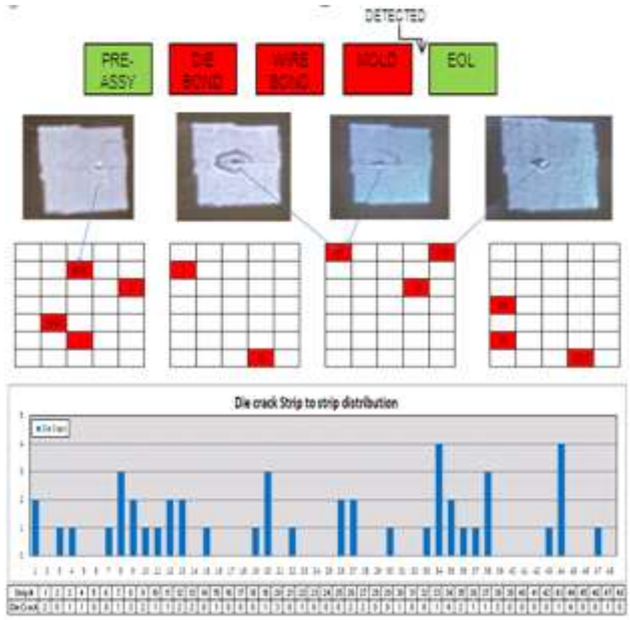


Fig. 10. Die crack process mapping

2.1.4 *Die crack mapping at mold*

It was observe that substrate solder resist was embedded on bottom tool surface which coincides to the location of die crack during SCAT verification

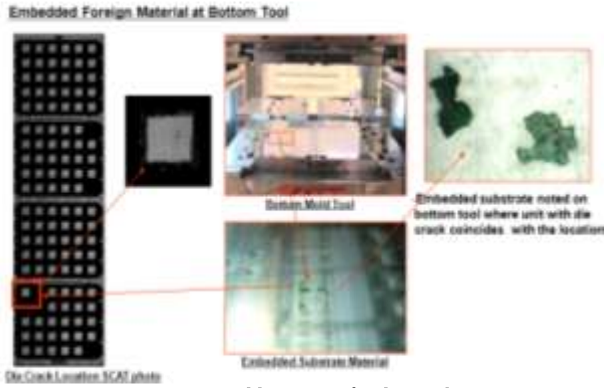


Fig. 11. Mold mapping for die crack

2.1.5 *Foreign Material Sources leading to die crack*

Based from brainstorming, the below list are the possible sources of foreign material at mold that can lead to die crack once embedded on bottom tool.

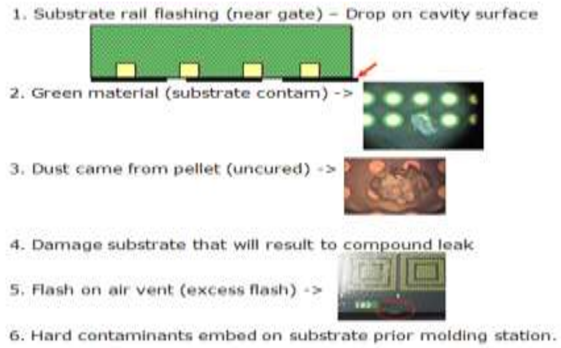


Fig. 12. List of foreign material sources at mold

2.1.6 *Fault tree diagram for die crack due to foreign material*

Based from the fault tree there are several potential root cause of foreign materials at mold that will lead to die crack but not all lead to gross rejection. This is aggravated by the current cleaning capability which prevents cleaning of bottom tool due to restriction of vacuum holes being clogged by the cleaning process.

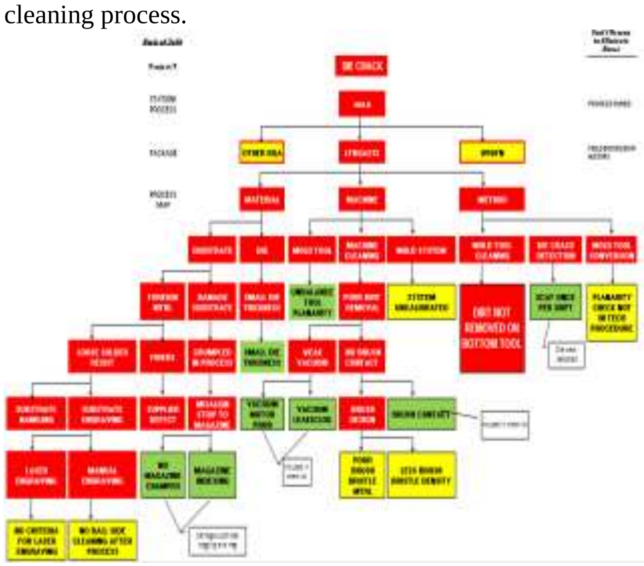


Fig. 13. LFBGA273 die crack fault tree diagram

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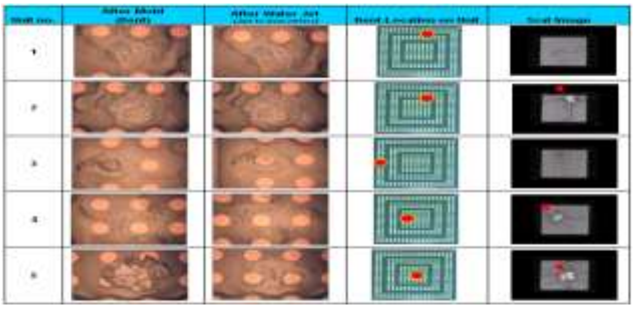
III. Results and Discussion

3.1 Simulation of Foreign Material on Bottom Tool

Conducted simulation to confirm die crack observed from the mapping by placing uncured pellet powder and solder resist flakes on bottom tool and subject strips of LFBGA273 with die to molding process by verifying SCAT response. Results showed that die crack was replicated via uncured pellet and solder resist on bottom tool.

Table 2. Simulation matrix for LFBGA273 die crack



3.2 _Material Verification of Lots with Die Crack

Inspection of lots processed revealed units with bleed of mold compound on substrate backside and loose solder resist on laser engraved substrate rejects.

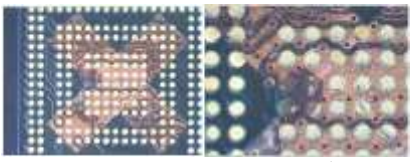


Fig. 14. Mold compound bleeding the backside from supplier reject

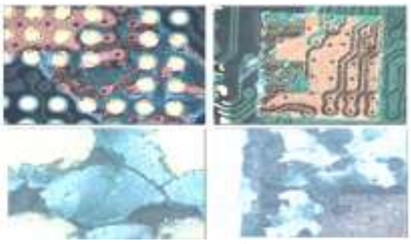


Fig. 15. Loose solder resist from supplier reject

Also inspected fresh substrate from same batch revealed damage substrates and foreign material on supplier rejects that can lead to die crack.

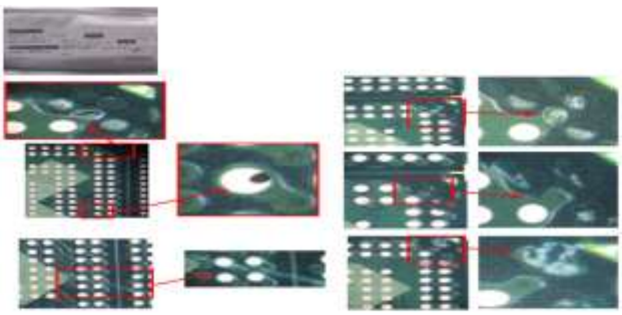


Fig. 16. Fresh substrate inspection result on supplier rejects

3.2.1 Pin light penetration test

Pin Light penetration test was also conducted to confirm substrate holes on affected batch. Light penetrated across the engrave part of the substrate

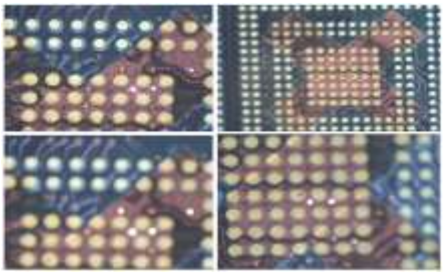


Fig. 17. Pin light penetration test for substrate holes

3.3 Comparison of Good and Bad Substrate Batch

Based from comparison of good and affected bad parts deep laser engraving was noted on bad parts which leads substrate holes causing mold compound bleed and loose solder resist flakes.

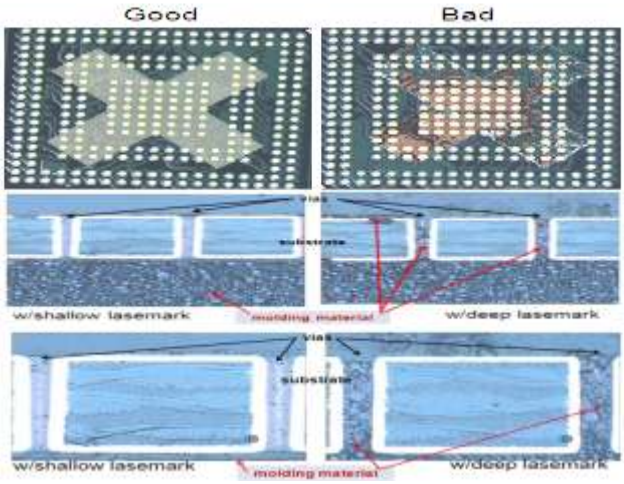


Fig. 18. X-ray and delamination sample for different pellet weight

3.4 Implementation Phase

3.4.1 Corrective action

With the confirmation of the root cause to be attributed to the affected substrate batch, immediate scrapping of the remaining substrates was executed. Affected lots at test was risk assess to be captured by test program while lots at assembly was subject to SCAT.

Effectiveness validation of corrective action was done at assembly via SCAT and confirmed by test results with no lots exceeding 0.3% for TN362 and TN500 test bins on more than 100 consecutive lots.

Fig. 19. LFBGA273 Test die crack validation

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3.4.2 Preventive action

3.4.2.1 Loose foreign material removal on tool

It was observed that not all loose debris are being removed by the sweeper brush and roller features of the mold machine due to the bristle configuration. A purchase order has already been raised to make the bristle design more fine as shown below.

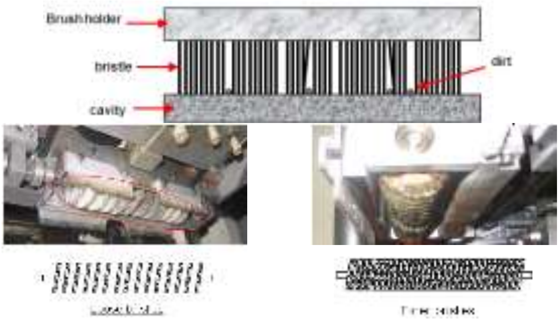

Fig. 20. Mold sweeper brush and bristle configuration

With the current cleaning capability which prevents cleaning of bottom tool due to restriction of vacuum holes being clogged by the cleaning process, several alternative cleaning process was considered to execute bottom tool cleaning

Table 3. Bottom tool cleaning selection matrix

Material/ Process	Status	Output Response: Bottom tool cleaning	Output Response: Vacuum hole clogging	Remarks
Cleaning cloth	current	failed	failed	Cleaning is subjective
Chemical cleaning	current	passed	passed	Freq. not real time, downtime
Sand blasting	current	passed	failed	Downtime
Plasma cleaning	not evaluated	not applicable	not applicable	High investement cost
Mold Liner				
RB 142	Failed	passed	failed	Material tearing
RB 149	Failed	passed	failed	Material tearing
RB 839	Passed	passed	passed	

Legend: passed (green), failed (red), not applicable (white)

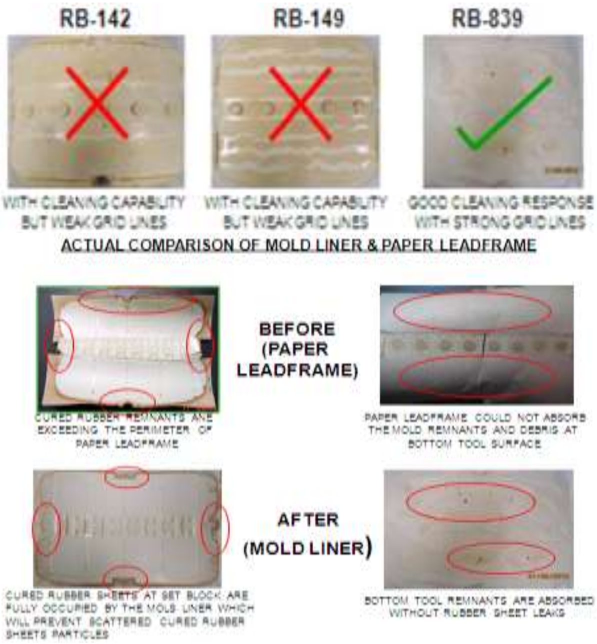

Fig. 21. Mold liner grade sample and comparison to paper leadframe

3.4.2.2 Other foreign material sources

Most of the damage substrates encountered was broken corners of strips which are due to machine alignment variation to sharp edges of the substrate corners. Substrate drawings was revised to have chamfer at corners

Cull flashing due to tool planarity was addressed via mold tool PM every 3 months while for cull flashing due to worn out parts Tool Algo will be executed for proactive replacement.

3.4.3 Control phase

To provide real time process control for die crack detection at assembly, it was agreed that SCAT monitoring will be performed every 12 hrs per press per machine. As a result, die crack occurrence at test was zeroed out starting Q4'10 after implementation of mold liner.

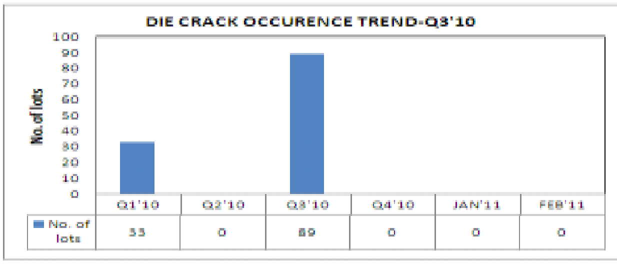

Fig. 22. Die crack occurrence at test trend

IV. Conclusion

We conclude therefore that LFBGA273 die crack was due foreign material cross contamination from a discrepant substrate batch which was embedded on bottom tool, mold compound and solder resist flakes. Improvement of mold tool cleaning via mold liner can effectively remove embedded foreign material from bottom tool. Inclusion of SCAT monitoring at mold is also an effective control to contain problem at source and not reach test.

V. Recommendations

It is recommended to update the Corporate specs pertaining to substrate incoming inspection criteria and purchasing specification to include substrate reject on visual inspection to prevent escape of substrates with foreign materials and/or holes on supplier declared rejects from reaching production floor.

Continuous improvement of damage substrates from assembly is also essential in preventing future cases of die crack and mold tool maintenance to reduce foreign material from mold process.

Acknowledgment

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from CPA for the finite element analysis. The entire mold team consisting of process, equipment, production and process control who collectively join hands to resolve the problem.

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