EXCESSIVE FLASHING REDUCTION ON PLAD SINGLE-DIE/ BI-RECTIONAL DEVICES THRU STACK HEIGHT ANALYSIS

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ABSTRACT

PLAD or Plastic Large Area Device are surface mount package devices with typical applications in lightning and automotive load dump protection. The PLAD package combines a large die size with a large exposed bottom-side metal slug for heat sinking that improves power handling as compared to through-hole package designs.

Molding process encapsulates the die-moly-metal slug assembly using molding compound in such a way that the resulting composite materials are robustly protected and functions to its intended purpose as shown in Fig 1. However, due to process and equipment variations, product yield is affected. Defects such as mold flashing and package chip-out are the top defects affecting this package. Such defects resulted to yield loss, production cost loss and customer concerns.

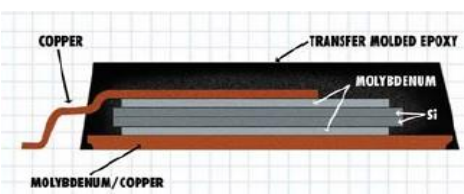


Fig 1: PLAD device parts

Re-engineering and modification of leadframe bend in PLAD15KPCA devices results in significant improvements in terms of productivity, costs and quality. This is expounded into a detailed information on the following sections of this paper.

1.0 INTRODUCTION

Four assembly types comprises PLAD package family. As shown on Fig 2, these package configuration are:

A. Dual-die/ bi-directional devices
B. Dual-die/ uni- directional devices
C. Single-die/ bi-directional devices
D. Single-die/ uni-directional devices

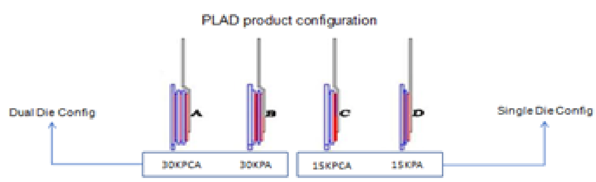


Fig 3: PLAD Product configuration

Each package type has different response in terms of flashing when encapsulated. Single-die assembly tends to have severe/ excessive flashing on heatsink side of the package. Flashing or mold flash are excess plastic material to a molded product which must usually be removed. In PLAD process, manual deflash is performed; manual deflash is typically conducted using hand deflashing tool, sand paper, eraser or equivalent.

1.1 Problem description:

Inherent mold flashing on heatsink area (as shown on Fig 3) of single-die/ bi-directional or 15KPCA devices of PLAD package causes low UPH on deflashing process. Such heavy flashing induce process difficulty and prolonged cycle time on manual deflash. Aside from this low UPH, defect ppm is also affected due to package chip-out rejections caused by this excessive flashing on heatsink.

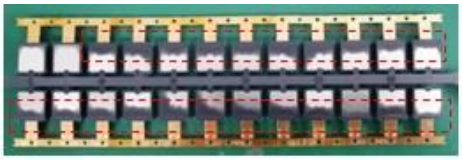


Fig 3: Heatsink flashing signature of PLAD15KPCA

Based on PLAD UPH matrix for Manual Deflash process, there was additional process cost of $4.2K for lots with 87.7% flashing defect rate.

PLAD Manual Deflash UPH Matrix

PACKAGE	DESCRIPTION	UPH	PROCESS COST PER UNIT	VOLUME 2022	COST PER PROCESS	ADDITIONAL COST	UPH LOSS
PLAD-15KP	ORIGINAL	186	$0.0189	160,000	$3,027.96	$4,192.55	58.06%
	BK DIE - 87.7% FLASHING	78	$0.0451		$7,220.51		

Fig 4: UPH Matrix for Manual Deflash

As shown on funnel/ bottleneck process chart, Manual deflash process UPH was further reduced from 186 UPH to 78 UPH or reduction of 58.06% due to excessive flashing on 15KPCA devices.

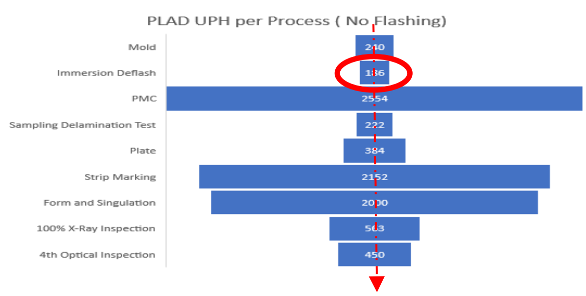


Fig 5: Manual Deflash UPH without flashing

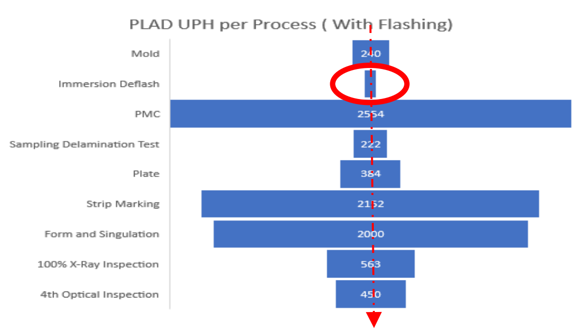


Fig 6: Manual Deflash UPH with flashing

PPM rejection rate for package chip-out (2.84 KPPM) also increased due to difficulty in removing the thick flashing manually.

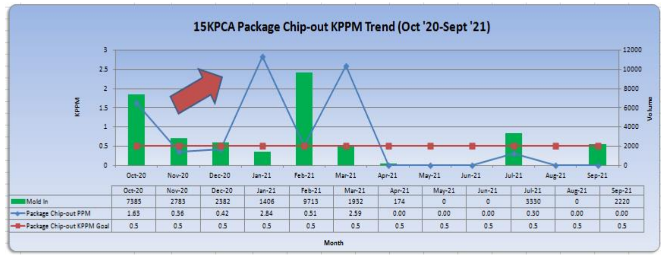


Fig 7: PPM Trend of Package Chip-out for 15KPCA

3.0 METHODOLOGY

- Use fish bone diagram for rootcause analysis.
- Analyze and validate potential causes of defects.
- Qualified and gather all needed data and institute improvements.
- Perform identified actionables and gather results.
- Perform the final qualification and documentations
- Utilize by production and monitor effectiveness.

3.1 Failure Analysis:

Fishbone Analysis for Excessive Flashing.

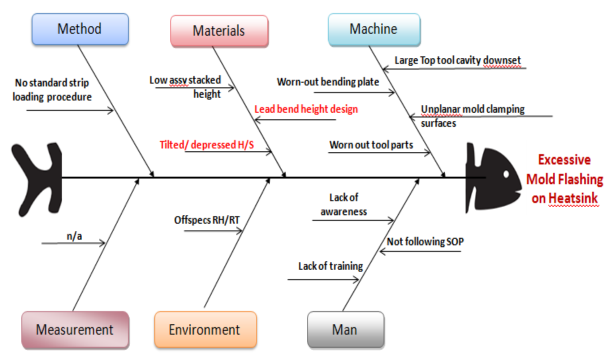


Figure 8: Fishbone Analysis of Excessive Flashing on 15KPCA

3.2.1 Validation

1. Material

<u>- Tilted/ depressed heatsink</u>
<u>- Low/ High assembly stacked height</u>

Based on current molded units, it was observed that the heavy flashing is evident on leadside of the strips. Further measurement and failure analysis showed the heatsink is tilted on leadside and not planar with respect to the plastic mold of the units.

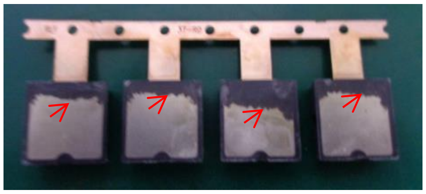
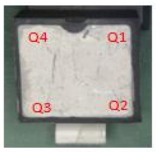


Fig 9: Heavy mold flashing on lead side of the molded strips

Tilted/ Depressed Heatsink

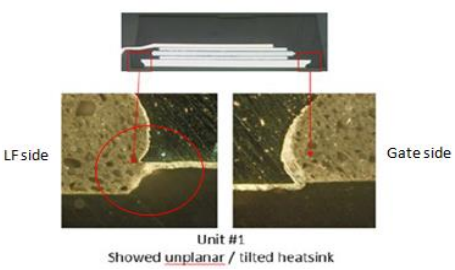
Unit #	Q1	Q2	Q3	Q4
1	+0.010	-0.082	-0.043	+0.028
2	+0.028	-0.080	-0.040	+0.026
3	+0.012	-0.073	-0.020	+0.033

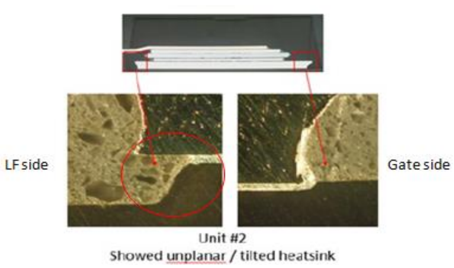


Planar Heatsink - VZ POS Rej

Unit #	Q1	Q2	Q3	Q4
A	+0.026	+0.003	+0.008	+0.025
B	+0.024	+0.002	+0.004	+0.022

As shown on heatsink surface measurement, sides Q2 and Q3 on affected units have depression of 0.020 to 0.082mm whereas the units with no flashing have no indications of depressed heatsink. Cross-section showed unplanar heatsink, see Fig 10.





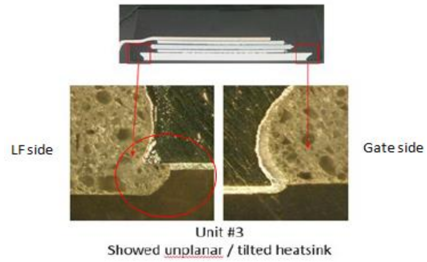


Fig 10: Cross-section of units with flashing on heatsink

Units without flashing on heatsink have evident planar heatsink with respect to the plastic mold perimeters shown of Fig 11.

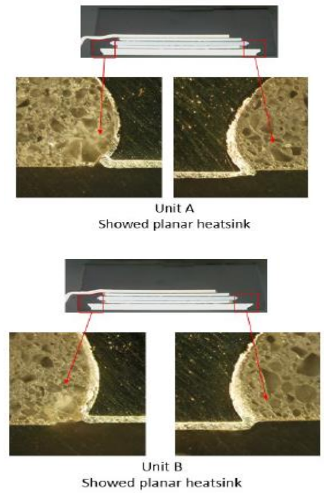
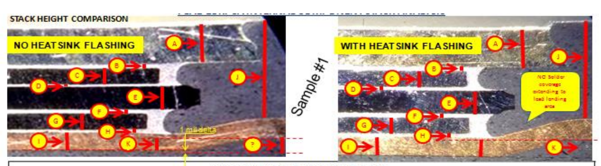


Fig 11: Cross-section of units without flashing on heatsink

<u>- Assembly Internal Component Stack Height Analysis</u>

Cross-section analysis was conducted in order to compare assembly stacked height of good units and affected units. Based on layer measurement of the assembly as shown in Fig 12, it was noted that the units without flashing have low lead bend, 6.8.5mils, compared to the standard lead bend which is 9-10 mils.

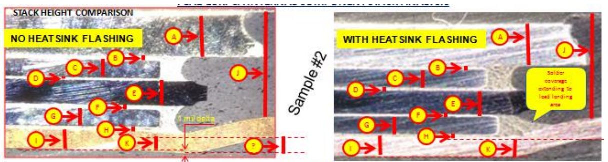


COMPONENT HEIGHT COMPARISON (in inch)

	GATE SIDE			LEAD SIDE			
HEIGHT CODE	NO HS FLASHING	WITH HS FLASHING	DELTA	NO HS FLASHING	WITH HSFLASHING	DELTA	REMARKS
A (heatsink)	0.02050	0.02030	0.0002	0.02045	0.02005	0.0004	
B (solder)	0.00230	0.00290	0.0006	0.00185	0.00140	0.00045	TOTAL HEIGHT – K– I 0.06670 – 0.00930 – 0.01030 = 0.0471 Short by 0.0043 or 4.3 mils to Touch the top mold surface must be equal to J: 0.05140
C (moly)	0.00885	0.00890	0.00005	0.00875	0.00880	0.00005	
D (solder)	0.00095	0.00155	0.0006	0.00115	0.00200	0.00085	
E (silicon die)	0.01280	0.01255	0.00025	0.01260	0.01230	0.0003	
F (solder)	0.00175	0.00205	0.0003	0.00175	0.00165	0.0001	
G (moly)	0.00890	0.00825	0.00065	0.00900	0.00865	.000035	
H (solder)	0.00175	0.00140	0.00035	0.00125	0.00155	0.0003	
I (leadframe)	0.01010	0.01050	.00040	0.01045	0.01030	0.00015	
J (half pkg height)	N/A	N/A	-	0.05150	0.05140	0.0001	
K (bending height)	N/A	N/A	-	0.00685	0.00930	0.00245	Slight pressing down on bending area
Total height (A to I)	0.0679	0.0684	0.0005	0.06725	0.06670	0.00055	

Fig 12: Assembly Stack height

Further validation on another set of samples showed lead bend height of 6.15mils on samples without flashing.



COMPONENT HEIGHT COMPARISON (in inch)							
	GATE SIDE			LEAD SIDE			
HEIGHT CODE	NO HS FLASHING	WITH HS FLASHING	DELTA	NO HS FLASHING	WITH HSFLASHING	DELTA	REMARKS
A (heatsink)	0.02025	0.02055	0.0003	0.02055	0.02015	0.0004	
B (solder)	0.00190	0.00160	0.0003	0.00170	0.00155	0.00015	TOTAL HEIGHT – K– I 0.06655 – 0.00935 – 0.01005 = 0.04715 Short by 0.0046 or 4.6 mils to touch the top mold surface must be equal to J: 0.05175
C (moly)	0.00915	0.01000	0.00085	0.00930	0.00975	0.00045	
D (solder)	0.00155	0.00150	0.00005	0.00100	0.00110	0.0001	
E (silicon die)	0.01245	0.01245	0.0000	0.01240	0.01240	0.0000	
F (solder)	0.00140	0.00085	0.00055	0.00175	0.00085	0.0009	
G (moly)	0.00880	0.00935	0.00055	0.00890	0.00970	0.0008	
H (solder)	0.00140	0.00100	0.0004	0.00195	0.00100	0.00095	
I (leadframe)	0.01010	0.01020	0.0001	0.01015	0.01005	0.0001	
J (half pkg height)	N/A	N/A	-	0.05180	0.05175	0.00005	
K (bending height)	N/A	N/A	-	.00615	0.00935	0.00320	Slight pressing down on bending area
Total height (A to I)	0.0670	0.0675	0.0005	0.0677	0.06655	0.00115	

Fig 13: Assembly Stack height

No Heatsink Flashing as shown in Fig 14:

- Two (2) units samples of units with NO FLASHING on heatsink showed the depressed area of lead bending adjacent to moly. It is an indication of lead bending height is below the minimum that potentially contributed by bending tool variation.
- Based on data, low bending height can eliminate the flashing on heatsink as it reached and touching the top mold surface.
- Bending height of with and without flashing showed the 2.5 mils and 3.2 mils delta

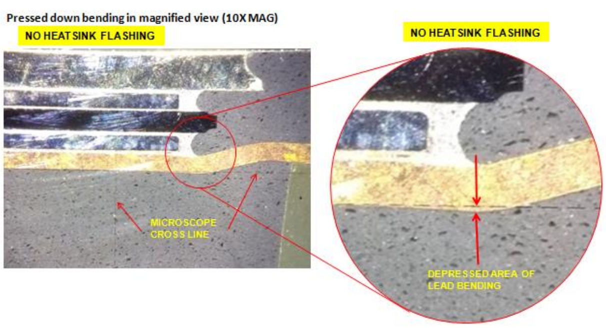


Fig 14: No HS flashing with pressing down of lead bend

WITH Heatsink Flashing as shown in Fig 15:

- No abnormality noted on internal component stuck height measurement.

- No abnormality noted on lead bending and all passed the requirements. (*No depressed lead bending)*

- Bending height within the requirements do not touch the top mold surface thus creating the heavy flashing on heatsink.

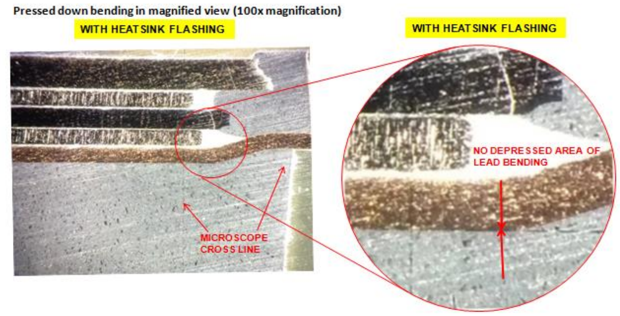
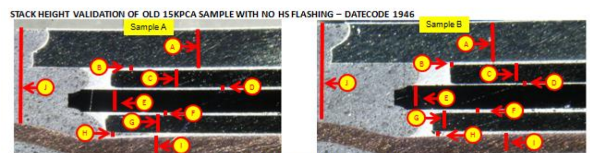


Fig 15: With HS flashing with pressing down of lead bend

Old Samples With No HS Flashing – Datecode 1946

Component cross-section on Fig 16:

- Both samples showed slight pressing down on bending area (delta of 2.2 and 1.85 mils).
- Gap between leadframe and moly



COMPONENT HEIGHT COMPARISON (in inch)							
	GATE SIDE			LEAD SIDE			
HEIGHT CODE	NO HS FLASHING A	NO HS FLASHING A	DELTA	NO HS FLASHING A	NO HS FLASHING B	DELTA	REMARKS
A (heatsink)	0.02000	0.02010	0.0001	0.02045	0.02010	0.00035	
B (solder)	0.00230	0.00250	0.0002	0.00175	0.00140	0.00035	
C (moly)	0.00900	0.00975	0.00075	0.00905	0.00955	0.00045	
D (solder)	0.00175	0.00185	0.00005	0.00135	0.00090	0.00045	
E (silicon die)	0.01220	0.01215	0.00005	0.01230	0.01210	0.0002	
F (solder)	0.00130	0.00160	0.0003	0.00155	0.00200	0.00045	
G (moly)	0.00935	0.00930	0.00005	0.00950	0.00935	0.00015	
H (solder)	0.00125	0.00145	0.0002	0.00325	0.00230	0.00095	Gap between LF and moly.
I (leadframe)	0.01010	0.01005	0.00005	0.01045	0.01015	0.0003	
J (half pkg height)	N/A	N/A	-	0.05110	0.05070	0.0004	
K (bending height)	N/A	N/A	-	0.00600	0.00565	0.00035	Both sample with slight pressing down on bending area (delta of 2.2 and 1.85 mils)
Total height (A to I)	0.0670	0.0675	0.0005	0.06665	0.06675	0.00115	

Fig 16: Old samples with No HS flashing

Component Cross-section on Fig 17:

- 2/2 samples with NO FLASHING on heatsink showed similar depressed area of lead bending adjacent to moly.
- Depressed area of lead bending for both sample is 2.2 mils and 1.85 mils.
- Bending height of 5.65 – 6.0 mils on both samples with No HS Flashing (Specs: 9- 11 mils)
- Gap on between leadframe and moly on Leadframeside due to depressed area of leadbend.

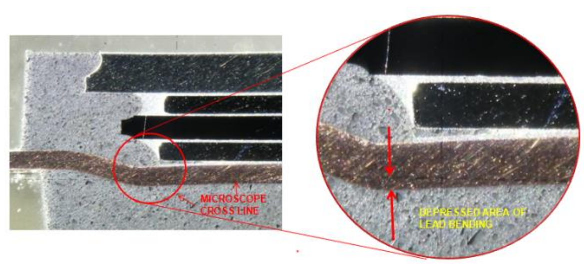


Fig 17: Old samples with No HS flashing

3.3 Experimental Section

3.3.1 Objective

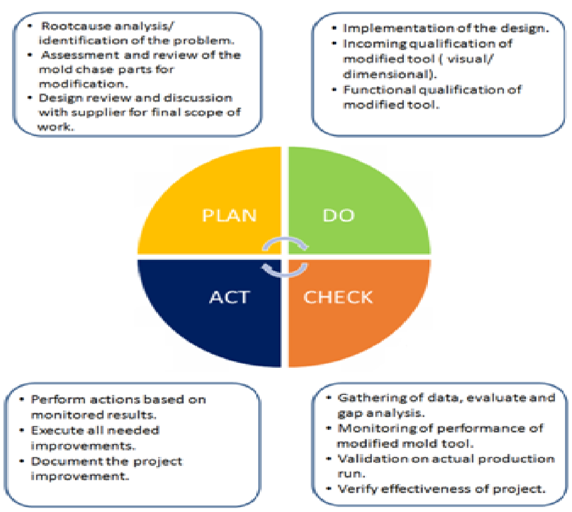
- To identify and analyze the causes of excessive flashing on heatsink.
- To improve the UPH in Manual Deflash process of PLAD for 15KPCA.

3.3.2 Equipment and Materials

- Bending Press and tool
- Mold chase
- Mold press
- PLAD strips (bend/ unbended)
- Epoxy Molding compound
- Plasma machine
- Argon gas
- CDA Box
- C-SAM machine
- Profile Projector

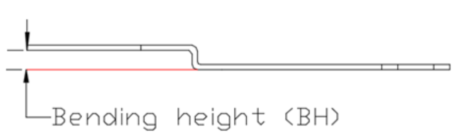
3.4 Use the PDCA to execute the project

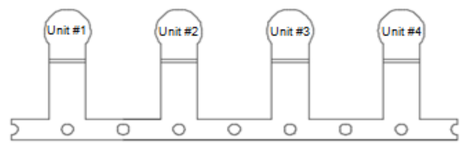
With the results of rootcause definition and validation, the following actions are defined per Plan-Do-Check-Act method:



3.5 Project Implementation

3.5.1 PLAD15KPCA Lead bend height Change





Lead Bending Data for 8.5mils bend height

Strap #	Bend Height (mils)			
	Unit 1	Unit 2	Unit 3	Unit 4
1	8.5	8.7	8.6	8.7
2	8.6	8.6	8.6	8.7
3	8.7	8.6	8.8	8.8
4	8.6	8.6	8.7	8.8
5	8.7	8.7	8.7	8.5
6	8.6	8.7	8.5	8.6
7	8.5	8.8	8.7	8.8
Min	8.5	8.6	8.5	8.5
Max	8.7	8.8	8.8	8.8
Average	8.6	8.7	8.7	8.7
StDev	0.08	0.08	0.10	0.12

Flashing Response on Evaluated Lead Bend Height:

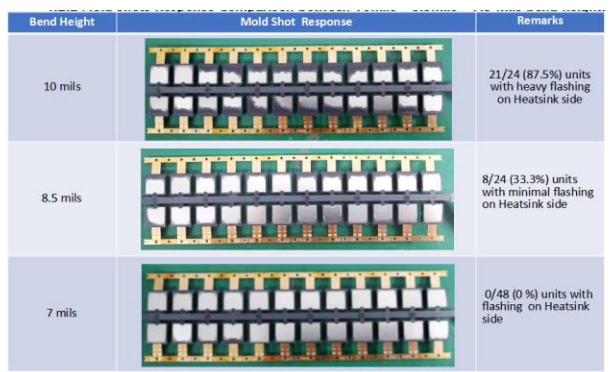


Fig 18: Mold Shot response per Lead bend height

4.0 RESULTS AND DISCUSSION

4.1 Evaluation Summary

Bend Height	Device No	Lot No	Run Quantity	3rd Opt Yield	Mold Shot Flashing Response (no flashing/ss)	Sampling Delamination Test (passed/ss)	DC1 Test (passed/ss)						4th Opt Yield	Electrical Test Yield (Lot)
							Pre-Mold	Post-Mold	Post-PMC	Post-Plate	Post Singulation	FT (DC Test)		
8.5 mils (1st Run - Evaluation)	MPLAD15KP160CA@	T305G03NK-1	240	98.75%	36/48	48/48	47/48	47/48	47/48	47/48	47/48	45/47	99.16%	77.87%
10 mils	MPLAD15KP160CA@	T305G03NK-1	240	98.33%	3/48	48/48	47/48	48/48	47/48	46/48	46/48	46/48	100%	74.15%
8.5 mils (2nd Run - Validation)	MPLAD15KP160CA@	TB02G06N	480	97.92%	30/48	48/48	48/48	47/48	47/48	46/48	46/48	44/48	99.79%	93.17%
8.5 mils (1st lot - Repeatability)	MPLAD15KP48CA@	U125G07N	181	95.58%	47/48	32/32	48/48	48/48	48/48	48/48	48/48	41/48	100.00%	85.55%
8.5 mils (2nd lot - Repeatability)	MPLAD15KP9.0CAE3@	U118G12PR-1	269	95.17%	48/48	32/32	48/48	48/48	48/48	48/48	48/48		100.00%	
8.5 mils (3rd lot - Repeatability)	MPLAD15KP48CA@	SA29G04N-4	139	96.40%	33/48	32/32	47/48	46/48	46/48	44/48	43/48	36/48	100.00%	85.07%

1. All bent straps passed bend height initial specification window of 7.5-9.5 mils.
2. Minimal thick flashing on heatsink observed on all strips molded for 8.5 mils bend. For 10 mils - 90% of the units have thick flashing on heatsink.

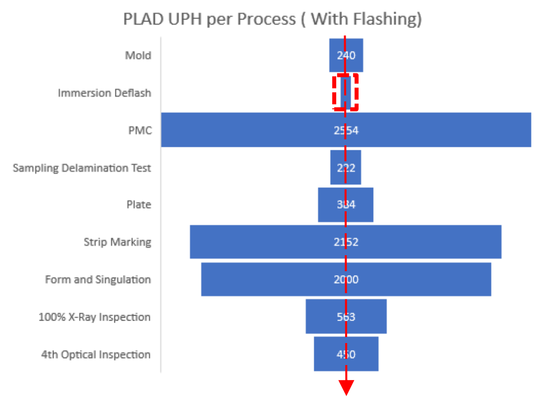
3. Low IR failure noted on DC Test conducted on identified Assembly process (Mold–Form) for 8.5mils bend repeatability evaluation.
4. No significant difference on Electrical Test yield between original and modified lad bend.

4.2 <u>Project Impact: UPH/ Quality</u>

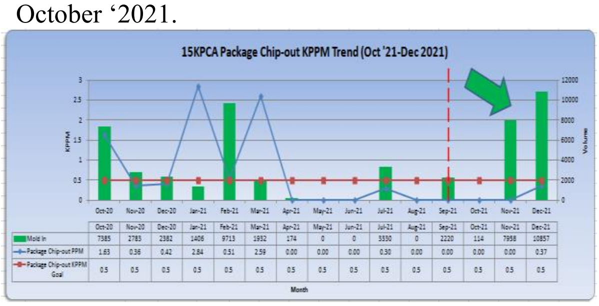
- <u>Cost avoidance</u> of $ 2.785K on process costs for 160000 units.

-<u>UPH</u> Improvement of 38.58% from 78 UPH to 127 UPH:

PACKAGE	DESCRIPTION	UPH	PROCESS COST PER UNIT	VOLUME 2022	COST PER PROCESS	COST IMPROVEMENT	UPH IMPROVEMENT
PLAD-15KP	ORIGINAL	186	$0.0189	160,000	$3,027.96		
	BK DIE - 87.7% FLASHING	78	$0.0451		$7,220.51	$2,785.86	38.58%
	33% FLASHING	127	$0.0277		$4,434.65		



- Package chip-out PPM reduction from 3 KPPM to 0.37 KPPM. New lead bend height implemented last October '2021.



4.3 <u>Tangible / Intangible benefits</u>

1. Improved cycle time in Manual Deflash process.
2. Ease of flashing removal for the production operators.
3. Reduce package chip-out defect ppm.

5.0 CONCLUSION

Based on study and evaluation conducted, the following project objectives were attained:

- Identified the root cause of excessive flashing and its solution which is lead bend height modification.
- UPH improvement in PLAD Manual Deflash process by 38.58%.

6.0 RECOMMENDATIONS

It is recommended to fan-out 8.5 mils bend height improvements to other single-die/ bi-directional devices (15KPCA). It is also recommended to study and conduct same evaluation on other PLAD devices with same flashing manifestations.

7.0 ACKNOWLEDGMENT

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8.0 REFERENCES

1. Technical Data Sheet – Surface Mount Transient Voltage Suppressor, MPLAD30KP14A-MPLAD30KP400CA.
2. Technical Data Sheet – EMC

9.0 ABOUT THE AUTHORS

Jason Sison is currently assigned in EOL Process Engineering; handling Niche and Small Black products as Process Engineer. A Fastech team member since July 13, 2015

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