INTRODUCTION OF DESCALING FOR THE IMPROVEMENT OF HALF CUT SINGULATION PROCESS OF WETTABLE FLANK QFN PACKAGES

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ABSTRACT

Wettable flank QFN is a well-known leadless surface-mount integrated circuit package that features a flat plastic body and solderable sidewalls that permit solder joint quality check through automatic visual inspection. In high-volume back-end assembly manufacturing, it is in the form of leadframe strip and usually exhibits non-uniform color due to Cu surface oxidation. Because of this non-uniformity appearance, there is difficulty in performing micro-target alignment during the half cut singulation process. This leads to frequent machine errors, high probability of misaligned cut occurrence, longer processing time and lower daily loading capacity of the half cut machine. In order to resolve these problems, the researchers in this work attempted to remove Cu surface oxidation of leadframes through introduction of descaling pre-treatment part of Sn plating process.

1. 0 INTRODUCTION

Quad Flat no Lead (QFN) is one of the semiconductor package solutions that offers compact footprint, excellent heat dissipation and superb electrical connections. Modification to its terminals has led to the introduction of integrated circuit package known as wettable flank QFN. Wettable flank QFN features solderable sidewalls that promote easy check of solder joint quality through automatic visual inspection. Solderable sidewalls of wettable flank QFNs can be created in the form of a) sidewall plated, which is produced by Sn immersion process, b) dimple, which is created via half-etching process of leadframe fabrication, c) curved punch, which is introduced by punching, and d) step cut, which is formed by half cut singulation. Selection of solderable sidewall options will depend on design requirements, manufacturing limitations, and intended application of the device[1-3, 8].

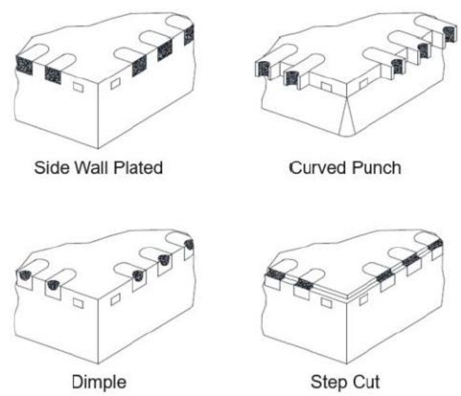


Fig. 1. Solderable sidewall options for wettable flank QFN[8]

A Sn plated, wettable flank QFN device with step cut is shown in Figure 2. In back-end assembly manufacturing, it is in leadframe strip form and normally undergoes several steps. Since most of these steps involved are operated at elevated temperatures (process in purple boxes in Figure 3), the leadframe strips, which is Cu-based, is normally oxidized. This leads to its non-uniform appearance as presented in Figure 4.

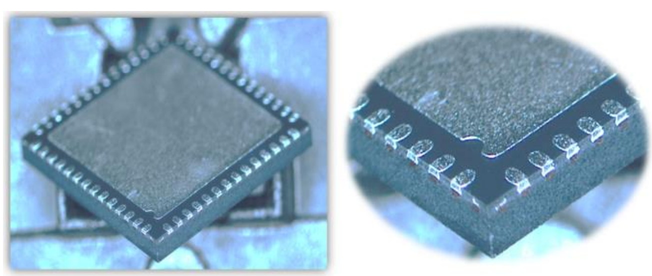


Fig. 2. wettable flank QFN with step cut

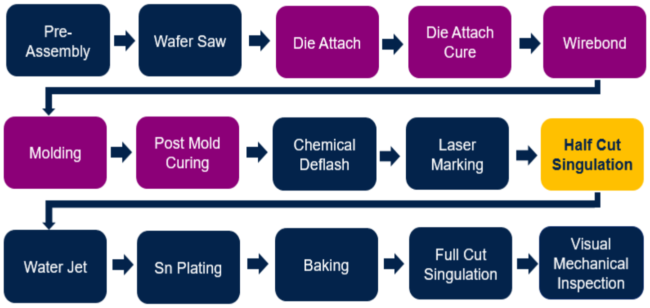


Fig. 3. Assembly process flow for wettable flank QFN packages

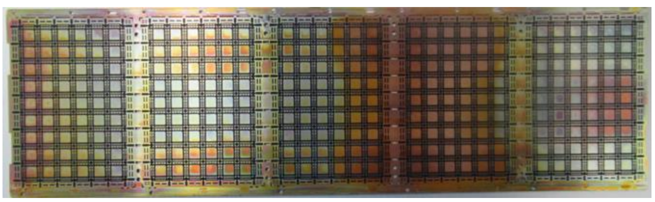


Fig. 4. Leadframe with surface oxidation

Because of this non-uniformity appearance of leadframes, there is difficulty in performing micro-target alignment in a half cut singulation process where pattern recognition is based on contrast. This results in problems such as frequent errors during processing, high probability of misaligned cut occurrence, longer processing time and lower daily loading capacity of the half-cut machine. In order to eliminate these problems, the researchers in this work attempted to remove Cu surface oxidation of leadframes through introduction of descaling pre-treatment part of Sn plating process.

Fig. 5. Contrast pattern alignment in singulation

Descaling is a plating pretreatment step of great importance. It is a chemical process that dissolves oxides from the surface of leadframes. With its micro-etching and surface roughening effect, descaling promotes mechanical interlocking and good adhesion between plating layer and the base metal[9].

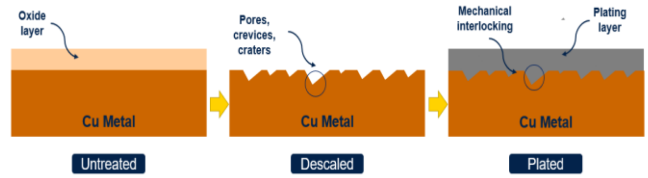


Fig. 6. Descaling process

2. 0 REVIEW OF RELATED WORK

Refer to 1.0 Introduction.

3.0 METHODOLOGY

Sample wettable flank QFN leadframes were processed in a Sn plating machine, where all process stations were deactivated except for descaling, post deionized water rinses and dryer sections (see Figure 7). A completely randomized experiment design was used, with belt speed served as the single independent variable. Three replicates were done for each treatment (4, 5, and 6 m/min belt speed) for a total of 9 experiment runs. All other important factors such as descaling chemical concentration and temperature were kept constant. The descaling chemical in this study is acidic and mainly composed of sodium persulfate.

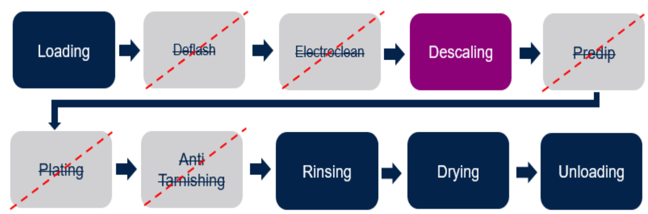


Fig. 7. Process flow inside Sn plating machine, descaling activated

Table 1. Completely randomized design matrix

Run	Pattern	Replicate	Treatment: Belt Speed in m/min	Response
1	-	1	4	Visual Quality, Microtarget Error Count, Stand-off in um
2	-	2	4	
3	-	3	4	
4	0	1	5	
5	0	2	5	
6	0	3	5	
7	+	1	6	
8	+	2	6	
9	+	3	6	

After doing all 9 experiment runs, each sample was visually inspected using an optical microscope. Stand-off, which is defined as the height between the surface of the mold and the surface of the Cu metal lead termination, was also measured 30 points for each sample using a profilometer. This measurement was done to check how aggressive the etching action of descaling process. Finally, the micro-target alignment error in half cut singulation machine was counted for each treatment. When all experimental results were gathered and arranged, statistical analysis of data was carried out through JMP® software.

To see how long will the descaled leadframes maintain their uniform appearance, two staging set-ups were also performed. In Set-up A, descaled leadframes were just placed on a rack inside the production line. Whereas in Set-up B, descaled leadframes were put in a more controlled environment inside an N_2 cabinet. Photographs were taken at 0^{th}, 4^{th}, 8^{th}, 24^{th}, 168^{th} (one week) and 672^{nd} (one month) hour of staging.

Fig. 8. Staging simulation in (a) rack and (b) N_2 cabinet

4.0 RESULTS AND DISCUSSION

4.1 Completely randomized experiment result

The actual completely randomized experiment matrix with corresponding response variables for each test run is presented in Table 2. From here, it can be observed that all obtained stand-off responses from each test run are within specification range of greater than 0 um.

Table 2. Average stand-off response

Run	Pattern	Replicate	Treatment: Belt Speed in m/min	Response: Average Stand-off in um (Target: > 0um, SS=30)
1	-	1	4	1.471
2	-	2	4	1.573
3	-	3	4	1.492
4	0	1	5	1.492
5	0	2	5	1.392
6	0	3	5	1.381
7	+	1	6	1.540
8	+	2	6	1.526
9	+	3	6	1.556

Bivariate analysis was performed by plotting belt speed against the stand-off measurement. It is presented in Figure 9. It can be noticed that the slope is almost flat, implying that there is a minimal change in stand-off when the belt speed is changed from 4 to 6 m/min. This is supported by the R square value of 0.009305, which indicates that there is only 0.9% change in the variation of stand-off measurement when the belt speed setting is changed. Also from the parameter estimates, the belt speed term has Prob > |t| value of 0.3658. Since it is greater than 0.05, it can be said that belt speed is not a significant factor at 95% confidence level.

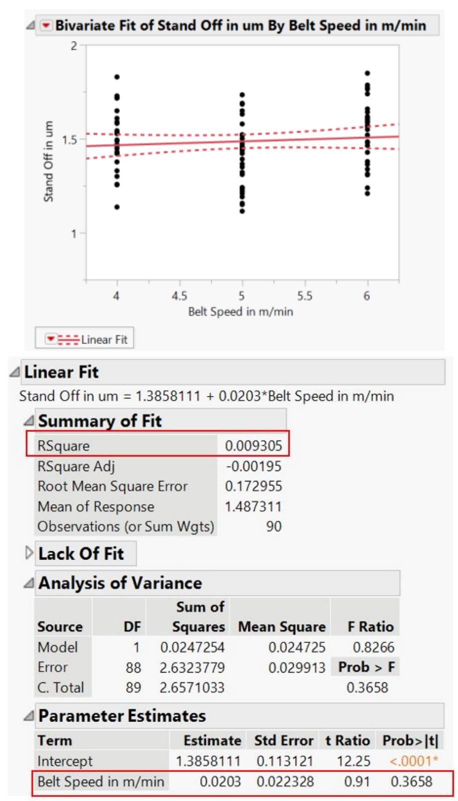


Fig. 9. Bivariate analysis

Photographs leadframes before and after descaling are shown in Figure 10. Leadframes achieved uniform appearance for all experimental runs. This suggests that in terms of visual quality, any belt speed can be used between 4 to 6 m/min.

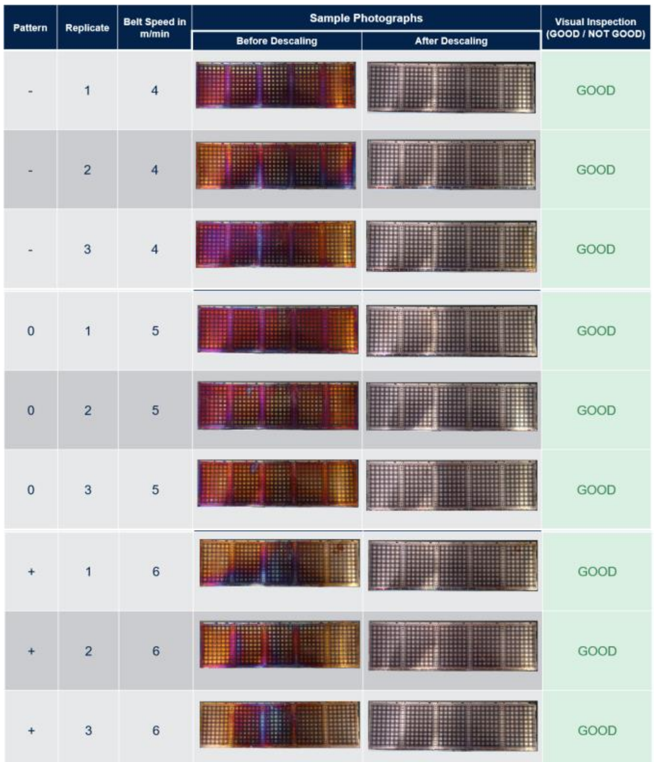


Fig. 10. Leadframes before and after descaling

Table 3 lists the micro-target error count recorded from each experimental runs. For all runs, zero micro-target error count was achieved during half cut singulation process. This led to shorter processing time, reflected by lower unscheduled downtime and higher machine utilization (see Figure 11).

Table 3. Micro-target error count

Run	Pattern	Replicate	Treatment: Belt Speed in m/min	Micro-target Error Count
1	-	1	4	0
2	-	2	4	0
3	-	3	4	0
4	0	1	5	0
5	0	2	5	0
6	0	3	5	0
7	+	1	6	0
8	+	2	6	0
9	+	3	6	0

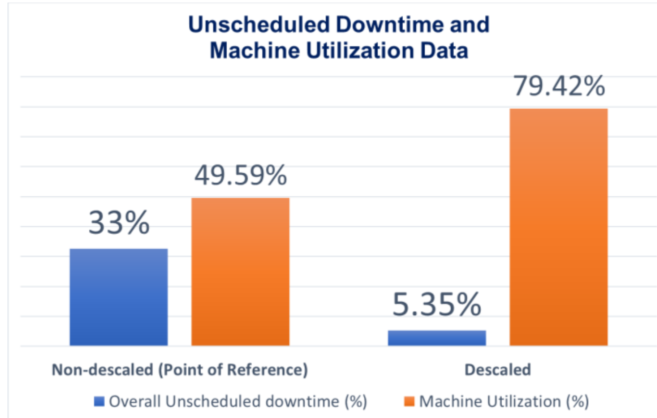


Fig. 11. Non-descaled vs descaled unscheduled downtime and machine utilization data

4.2 Descaled vs non-descaled stand-off comparison

Comparison of descaled and non-descaled leadframes was done to see if there is a significant difference between their stand-off measurements. The data distribution was first assessed by performing Shapiro-Wilk test of normality. From the result in Figure 12, the calculated P-value (Prob<W) is 0.3103. Since it is less than 0.05, it can be said that the data are normal at 95% confidence level.

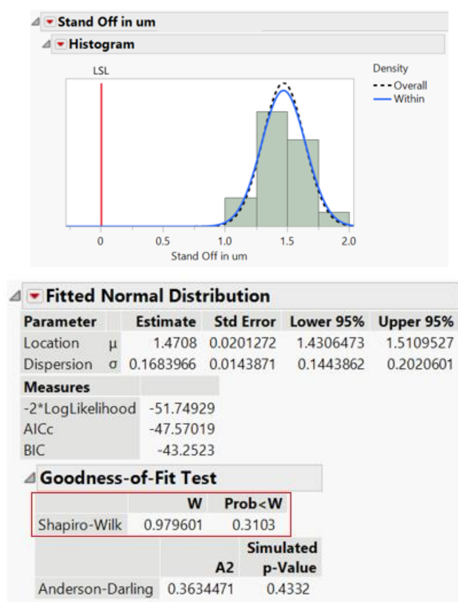
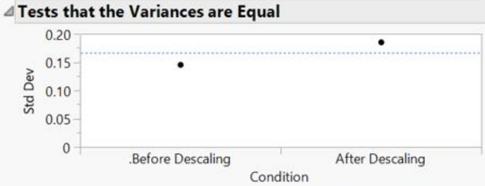


Fig. 12. Normality test

The test for equal variances was then performed. Because the data distribution is normal, F Test 2-sided was used. The computed Prob > F value at 95% confidence level is 0.1634 (see Figure 13). Because it is greater than $\alpha = 0.05$, it can be said that the variances of two inspection types are equal. There is also a small gap between the standard deviations of the two conditions. For non-descaled leadframe, the standard deviation is 0.14 while for descaled ones, it is 0.18.

Tests that the Variances are Equal



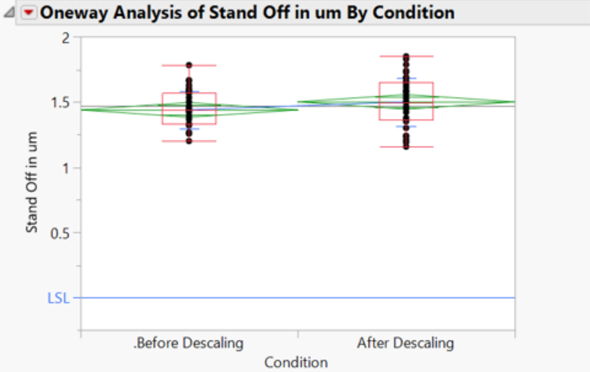
Level	Count	Std Dev	MeanAbsDif to Mean	MeanAbsDif to Median
.Before Descaling	35	0.1456305	0.1173061	0.1165143
After Descaling	35	0.1854875	0.1524702	0.1523429

Test	F Ratio	DFNum	DFDen	p-Value
O'Brien[.5]	2.7969	1	68	0.0990
Brown-Forsythe	2.5211	1	68	0.1170
Levene	2.4706	1	68	0.1206
Bartlett	1.9421	1	.	0.1634
F Test 2-sided	1.6223	34	34	0.1634

Fig. 13. Test for equal variances

Figure 14 shows the graph of leadframe condition against the stand-off. It is obvious from the graph the small difference between the stand-off of descaled and non-descaled leadframes. As both have equal variances, pooled t-Test was conducted for the mean. The resulting Prob > |t| value of the test was <0.1286. Thus, at 95% confidence level, there is no significant difference between the average stand-off of two leadframe conditions. For non-descaled leadframe, the mean stand-off is 1.44 um, while for the side pad inspection, it is just 1.50 um. This proves that the descaling process dissolves only the thin, sub-micron Cu oxide layer on the surface of leadframes and does not significantly etch the Cu metal.

Oneway Analysis of Stand Off in um By Condition



Oneway Anova

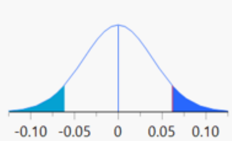
Summary of Fit

Rsquare	0.033624
Adj Rsquare	0.019412
Root Mean Square Error	0.166754
Mean of Response	1.4708
Observations (or Sum Wgts)	70

Pooled t Test

After Descaling-.Before Descaling
Assuming equal variances

Difference	0.06131	t Ratio	1.53817
Std Err Dif	0.03986	DF	68
Upper CL Dif	0.14086	Prob > |t|	0.1286
Lower CL Dif	-0.01823	Prob > t	0.0643
Confidence	0.95	Prob < t	0.9357



Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Condition	1	0.0657902	0.065790	2.3660	0.1286
Error	68	1.8908710	0.027807		
C. Total	69	1.9566612			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
.Before Descaling	35	1.44014	0.02819	1.3839	1.4964
After Descaling	35	1.50146	0.02819	1.4452	1.5577

Std Error uses a pooled estimate of error variance

Fig. 14. One way analysis of stand-off by leadframe condition

4.3 Staging simulation

Staging simulation results are shown in Figure 15. As can be noticed, the color uniformity of descaled leadframes was able to be maintained after a month of staging in rack and N_2 cabinet. It means that the leadframes have no risk of oxidation after descaling a in typical, class 10,000 manufacturing area.

Fig. 15. Staging simulation result

5.0 CONCLUSION

This work successfully demonstrated the capability of descaling process to remove surface oxidation of Cu-based leadframes without aggressive etching. The introduction of this process in the assembly of wettable flank QFN is effective in eliminating machine alignment errors during half cut singulation step and thus reducing its processing time and improving machine utilization. This paper may be considered a novel work as no technical paper has been written yet that used descaling as process solution for hairline adjustment problem in half cut singulation.

6.0 RECOMMENDATION

It is recommended that more experimental runs be made to confirm the results. The study of other descaling process factors is also proposed to be performed for further optimization.

7.0 ACKNOWLEDGMENT

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9.0 ABOUT THE AUTHORS

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