ETCHED TO STAMPED LEADFRAMES AS A COST-EFFECTIVE SOLUTION TO COPPER LEADFRAME SUPPLY

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ABSTRACT

Cost effectiveness is a universal goal in any kind of manufacturing and in any form of business. Stamping one standard and cost effective method that has stood the test of time.It is a process that is widely used but is thought to have been superseded by the better/ improved processes like chemical etching forming process.

An evaluation was done to transition from an etching leadframe forming process to a stamped forming process for cost saving reasons. The stamped leadframes were placed in assembly and yield was analyzed. This saw comparable performance to the current etched variant. Due to the forming limitations of the stamping process, some leadframe features lost due to the change to the stamping process which did not cause any issues with assembly.

Electrical testing and reliability were done which saw favorable results for temperature cycling (TC), unbiased highly accelerated stress test (UHAST) and high temperature storage life (HTSL). Lead integrity and solderability was also done with favorable results.

Overall, results were favorable, and no rejects were encountered that were attributed to the transition from etched to the stamped leadframe. The implementation of the stamped leadframe in the production pipeline dropped the per unit price of the leadframe by 11.59%

1. 0 INTRODUCTION

Copper is a high-priority metal in the semiconductor industry. The conductivity of copper is only rivalled by silver while being massively more abundant. Copper is also highly ductile and malleable. The combination of these properties has propelled copper to being one of the most used metals in the semiconductor industry.

Ductility is the ability of the material to be spun into wires while malleability is the ability of a material to be deformed with force or pressure. Both properties contribute to the ease of manufacturability of copper.

Stamping is a process of applying force and precision tools to form a sheet of metal into a desired shape.

In comparison, etching does not take advantage of mechanical properties like ductility and malleability but rather the inherent chemistry of the material. Etching uses specific chemicals like chlorides and acids depending on the metal to be etched, in this case it is copper. The chemical reaction between the metal and the etchant chemical forms the desired shape by chemically removing the unnecessary areas or portions of a metal.

Etching is advantageous to etching in a myriad of ways. Precision forming without burrs is the primary one. Another is the reduction of tooling cost and maintenance.

Stamping on the other hard is not without its merits. Stamping is better at manufacturing at high volumes due to typically higher units per hour (UPH). Stamping is also typically better in terms of mechanical properties.

The anticipated deterrent factors are the dimensional limitations as well as the lower precision of stamping. The study aims to see if those limitations apply to the leadframes used in Ampleon.

The advantage of etching in terms of precision while stamping being the most cost-effective option presents the problem statement of this study. Any manufacturing industry aims to achieve the perfect balance of cost effectiveness as well as maintaining a certain threshold in performance. This study aims to investigate stamping as a long-term and cost-effective solution.

2. 0 REVIEW OF RELATED WORK

Stamping is governed by cold working the copper material. Cold working means deforming a metal below its melting conditions. This means that physical properties like metallurgical grain size, residual stresses and material strength have a high influence on the efficiency of the process as well as the end resulting product.

The deformation causes strain hardening on the metal which causes an improvement in material strength (see Figure 2.1).

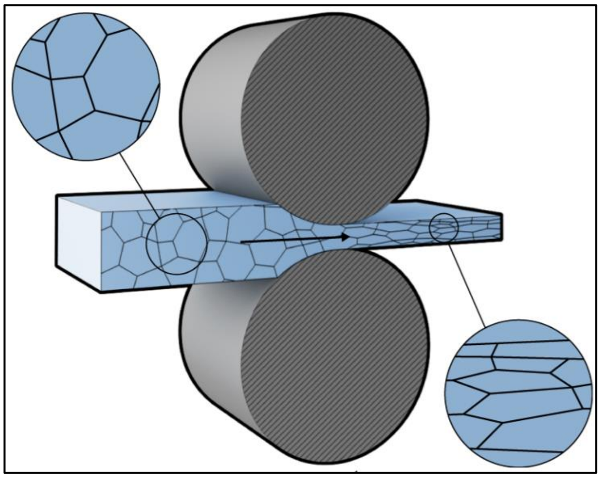

Fig 2.1 Illustration of what happens to metallic grains while cold working. Example given is through a compressive rolling process[2].

Figure 2.1 shows that grains become more compressed and lengthened during a compressive force. This can be done through rolling as shown in the image but same can be said by doing compression via stamping. This is only applicable in the area where the force is applied. The change in the grains compresses the structure as well as making it more ordered (meaning resembling a pattern). Both phenomena hinder the intergranular movement or dislocations which contributes to the improved mechanical strength done by cold working.

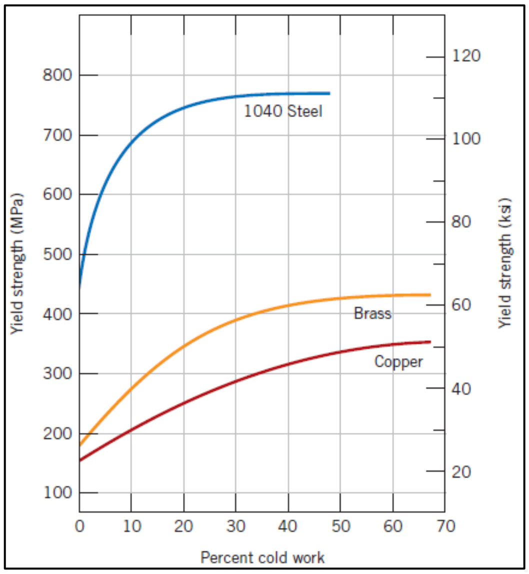

Fig 2.2 A sample plot of the effect of cold work to common metals, 1040 Steel, Brass and Copper (Callister)

Aside from strain hardening, residual stresses are being imparted to the material post cold work. This residual stress resists applied pressure to the material which also causes improvement in mechanical properties.

While stamping is a widely used process in manufacturing. Compared to etching, it is limited by its capability to provide complex forming and dimensions tolerancing. Initial investment also is high due to high CAPEX tooling costs.

3.0 METHODOLOGY.

Material characterization was done for the leadframes to be evaluated. Roughness (Ra) comparison was done using a Bruker Contour GT-K. Scanning Electron Microscopy (SEM) and Electron Dispersive X-ray Spectroscopy (EDX) along with cross section analysis were done to characterize the surface finish of the leadframe.

As for the evaluation plan, Ampleon's full assembly process will be done which includes diebond, wirebond, molding and electrical testing.

Reliability testing was done which includes temperature cycling (TC -65/150, 1000 Cycles), unbiased highly accelerated stress test (UHAST 130ºC/85% RH, 192Hrs) and high temperature storage life (HTSL at 175ºC, 1008Hrs). Preconditioning with MSL3 soak and 3x reflow was done prior TC and UHAST.

Solderability (dip and look, Dry bake and steam age) was done to ensure that quality and board-level customer application was not compromised in the stamped processing.

Additionally, lead integrity testing through lend bend and pull was also done.

4.0 RESULTS AND DISCUSSION

4.1 SEM/EDX Analysis for the Leadframe finish

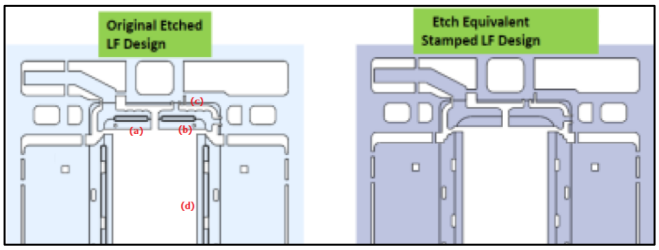

Fig 4.1 Preview of the changes in the leadframe design coming from the etched (left) to the stamped (right)

During the design phase of the material selection process, Ampleon and our supplier had addressed four key features that would be affected by the transition to stamping: (a) the shallow depth serving as a mold lock on the short side, (b) a small circle/hole on the inner periphery of the frame, (c) the corrugated mold locking mechanism on the side of the frame and the (d) shallow depth on the long side of the device similar to (b). Majority of the affected areas are concerned with the mold process. This is why it was important to establish a solid reliability requirement.

Overall, the design transition from etched to stamped leadframe considered that the result needed to be completely compatible with existing equipment in Ampleon so that a plug-and-play changeover can be done to maximize the already exiting capability in the facility.

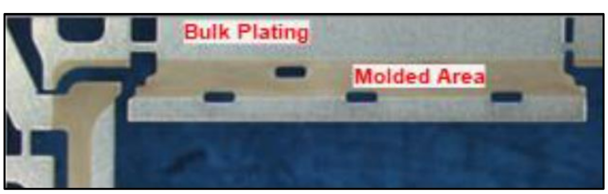

Fig 4.2 The two primary surface finishes of the leadframe, the bulk plated area and the mold plated area

Figure 4.2 shows the surface finishes of the leadframe. The bulk plated part is an electro plated layer while the molded area is another etched area designed to improve the adherence of a mold compound during successive processes. This is a different etching process and is not the etching forming process that is the main topic of this study, but rather a sample preparation step prior molding.

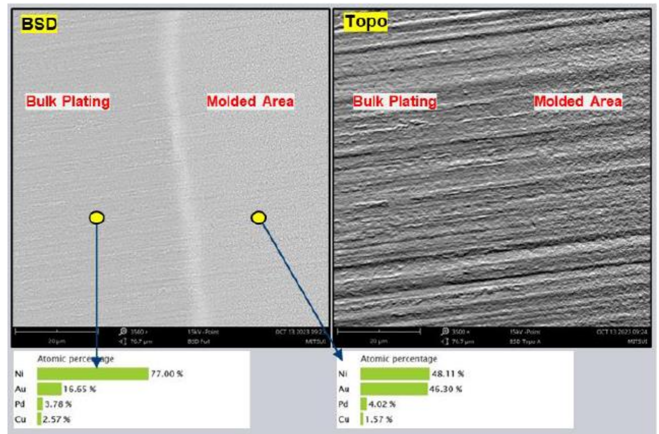

Fig 4.3 Top view SEM (BSD and Topography mode) + EDX of the surface finish of the etched leadframe

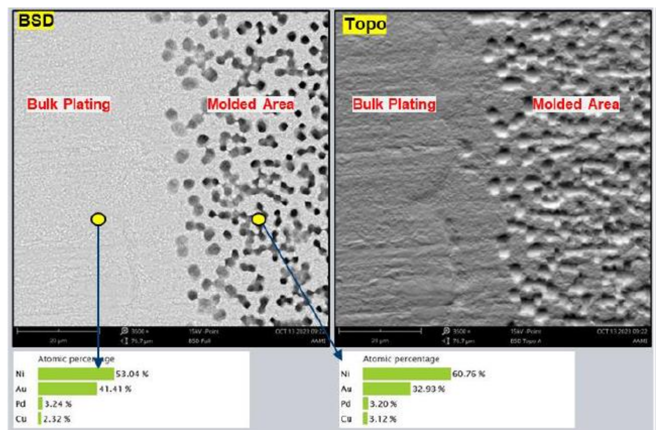

Fig 4.4 Top view SEM (BSD and Topography mode) + EDX of the surface finish of the stamped leadframe

The SEM of the bulk and plated area of the Etched and stamped variant shows difference topographical information. The molded area in particular shows a drastic difference between the etched and stamped parts.

The molded area of the stamped leadframe shows a rougher area compared to the etched leadframe. The roughening step done on the molded area is again a different and separate process compared to the etching/stamping forming step for these leadframes.

The rationale for this difference is that the replacement of the etching process on the stamped leadframes produced a surface finish with a lower activation energy. When producing these samples, the supplier encountered mold adhesion issue that was not present in the initial etched variant despite achieving the same roughness target. They opted to increase their roughening parameters to compensate for this. Overall, this is what caused noticeable roughening difference on the stamped leadframe.

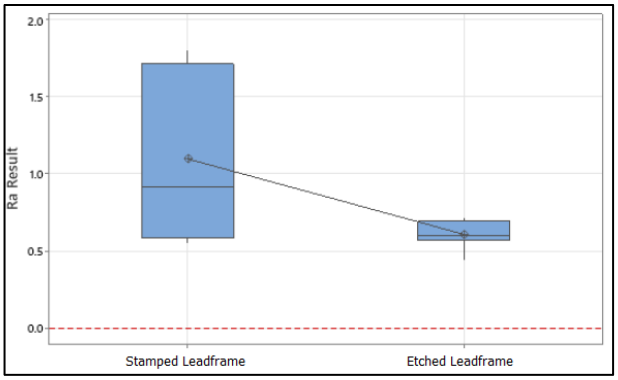

Fig 4.5 Boxplot showing the Roughness (Ra) delta needed on the molded area to compensate for the removal of the Etching leadframe forming process.

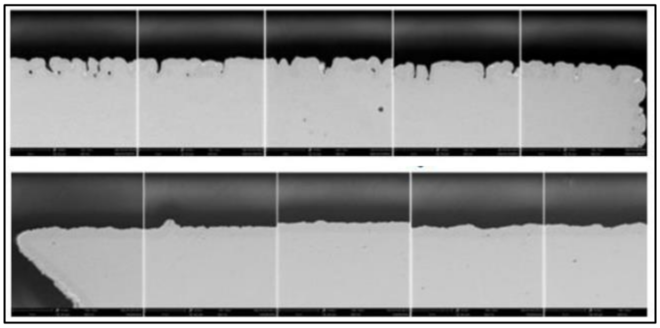

Fig 4.6 Side view SEM image of the molded area. (Top) Rougher stamped leadframe, (Bottom) Etched leadframe.

Increased roughening increases surface activation and therefore improves the adhesion of the mold compound.

4.2 Assembly Yield Results

Assembly results got a 96.77% yield for the etched samples then a 94.68% yield for stamped samples. While the stamped leadframes had a lower yield, the causes for the rejections were not related to the leadframe. This also includes in-line visual inspections where an internal visual criterion is implemented. No issues seen in terms of visual defects like dimensional defects and burrs.

Overall results were favorable for the stamped leadframe.

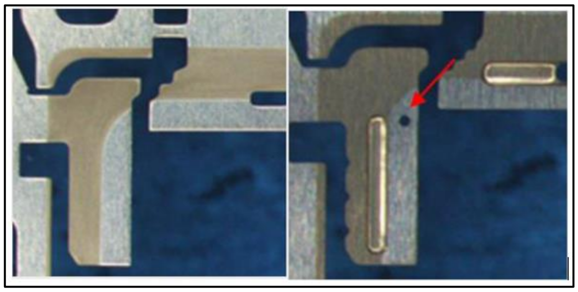

Fig 4.7 The etched hole seen on the right image on the etched leadframe is no longer present on the stamped leadframe on the left.

On Figure 4.7, the removal of an etched hole on the stamped leadframe led to a problem on the wirebond machine as it was being used for pattern recognition during material input. This was fixed by adjusting the pattern recognition program. This shows the importance of not only designing for performance but also designing for machine compatibility as well.

4.3 Reliability (TC, UHAST & HTSL)

Table 1: Tabulated summary of the reliability results

Reliability Process	Condition	Leadframe	Results
TC (with MSL3 Preconditioning + 3x Reflow)	-65/175C	Etched	Passed electrical test and visual inspection after Preconditioning then up until 1000 cycles. No rejects encountered that were related to leadframe
		Stamped	Passed electrical test and visual inspection after Preconditioning then up until 1000 cycles. Electrical rejects encountered but were not related to the leadframe.
uHAST (with MSL3 Preconditioning + 3x Reflow)	130C/85% RH	Etched	Passed electrical test and visual inspection after Preconditioning then up until 192 hours. No rejects encountered that were related to leadframe
		Stamped	Passed electrical test and visual inspection after Preconditioning then up until 192 hours. No rejects encountered that were related to leadframe
HTSL	175C	Etched	Passed electrical test and visual inspection after 1008 hours. No rejects encountered that were related to leadframe
		Stamped	Passed electrical test and visual inspection after 1008 hours. No rejects encountered that were related to leadframe

Table 1 shows the favorable results of the reliability testing done on both the etched and stamped samples.

4.4 Solderability and Lead Integrity Tests

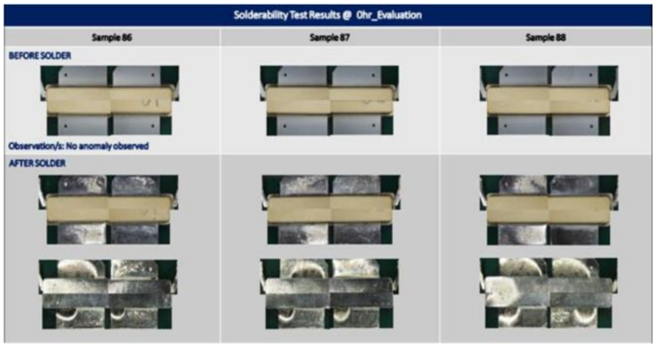

Fig 4.8 Solderability tests results for 0Hr dip and look, post dry-bake and post steam-age.

Results shown on figure 4.8 show that the leads formed from the stamped leadframe pass solderability at 0Hr, post Dry baking and post steam-ageing. 100% solder coverage was observed for all samples.

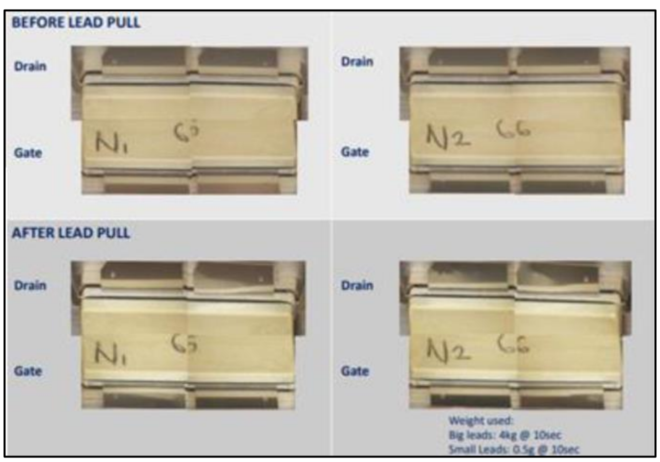

Fig 4.9 Lead pull integrity test results.

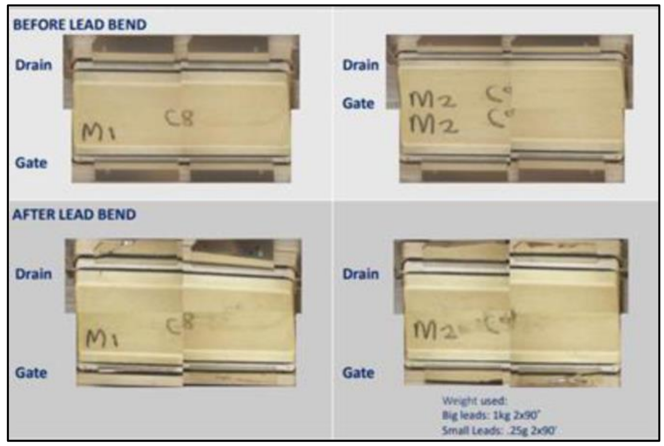

Fig 4.10 Lead bend integrity test results.

Lead integrity tests through lead pull and lead bending results show no package crack nor broken leads for stamped leadframes.

5.0 CONCLUSION

The transition from etched process to a stamped process presented risks on forming and dimensions tolerancing that were derisked in this evaluation. The stamped process is favorably more cost efficient compared to etching. This is the main reason to evaluate the possible switch.

The supplier identified some leadframe features that will be removed due to the stamping forming constraints. The evaluation saw that these features did not cause major issues with the yield and performance of the leadframe. Only one issue was encountered which is a pattern recognition issue in wirebond which was resolved outright.

Overall assembly yield on this change saw no issues on performance. Roughness delta was observed on the molded area of the leadframe which was seen during initial delivery, from the yield performance, this did not appear to affect the performance of the stamped leadframe both yield and test performance.

Evaluation was extended to TC, HTSL, UHAST, solderability and lead integrity tests, all of which passed the requirements.

Overall, the cost-effective transition from etched to stamped leadframes was effectively derisked thus the evaluation is successful. This change in the material will achieve an 11.59% price reduction for this material.

6.0 RECOMMENDATIONS

The study limited its scope to a single product line in the Ampleon product portfolio. This study could be a catalyst for more cost-effective changes. The context and idea for this came from the good partnership between customer and supplier.

7.0 ACKNOWLEDGMENT

The authors would like to thank the following for their support of this study:

- Mario De Vaan – Sr. Director, Quality & Reliability, Ampleon Phils., Inc.
- Olga Rivera – Director, Materials & Design Engineering/ Sustainability/ NPI-BET Quality, Ampleon Phils., Inc.
- Manolito Maalat – Sr. Manager, Failure Analysis/ Reliability and Calibration, Ampleon Phils., Inc.
- Jocy Castillo – Sr. Technician, Materials and Sustainability Engineering, Ampleon Phils., Inc.
- John Michael Tenorio – Junior Technician, Materials and Sustainability Engineering, Ampleon Phils., Inc.

8.0 REFERENCES

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2. "Cold rolling of sheets." Manufacturing Guide Sweden AB.

9.0 ABOUT THE AUTHORS

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