International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Ultra-Short Pulsed Laser Ablation of Epoxy Mold Compound or Copper Frames for Partial Cut QFNs

Ernesto Antilano Jr.[1], Ian Harvey Arellano[2]
[1]Central Engineering & Development, [2]Backend Manufacturing and Technology
STMicroelectronics, Inc., 9 Mountain Drive, LISP II, Calamba 4027 Laguna, Philippines

***Abstract*—** *Wettable flank technology is an emerging solution for the customer requirement of visually detectable solder joints for high reliability application. Herein, we present a strategy to realize this challenging technology. The use of ultra-short pulsed laser for the ablation of epoxy mold compound or copper frames to create the partial cut in a quad flat no lead (QFN) package resulted in the successful creation of a sidewall, which can be electroplated with solderable material such as tin to create wettable QFNs.*

***Keywords*—** *Filler, epoxy, adhesion, electrical failure, mrchanical stress.*

I. INTRODUCTION

The market drive towards visually detectable solder joints for high reliability applications calls for the implementation of robust wettable flank technologies [1-2], wherein copper terminations at the package edges exposed after package singulation are made solderable by plating the exposed copper to prevent oxidation [3-4] and promote consistent solderability [5]. During the standard assembly operation, Cu sidewalls are exposed after package singulation. Oxidation of these sidewalls occurs almost instantaneously upon exposure to ambient conditions. Oxidized sidewalls solder inconsistently, necessitating the introduction of sidewall plating, which acts as a protective layer against oxidation, and solder joint promoter due to material compatibility with the solder (Sn). These wettable flanks allow the solder to form fillets [5] (Fig. 1), which can be evaluated via optical inspection, indicating good electrical connectivity.

Several strategies are explored to realize these customer requirements on quad flat no lead (QFN) packages, such as 1) dimpled leadframe, 2) Sn immersion, 3) partial cut saw blade singulation, *etc.* [6-8]. Herein, we present another strategy involving the use of ultra-short pulsed laser ablation of epoxy mold compound or Cu frames to realize the initial cut (partial cut) followed by the conventional blade saw singulation to separate the units from each other.

II. EXPERIMENTAL DETAILS

Standard QFN package was assembled using standard process involving the attachment of a semiconductor die onto a copper leadframe using a die attach material, electrically connecting the die to the leadframe using a thin metal wire, and encapsulating the package using an epoxy molding compound. The partial cut was realized using a commercially available laser system with a wavelength of 1030 nm, an average power of 40 W, frequency range of 200 - 800 kHz, beam quality M^2 of less than 1.3, pulse energy of less than 200 μJ and pulse width of 800 ± 200 fs.

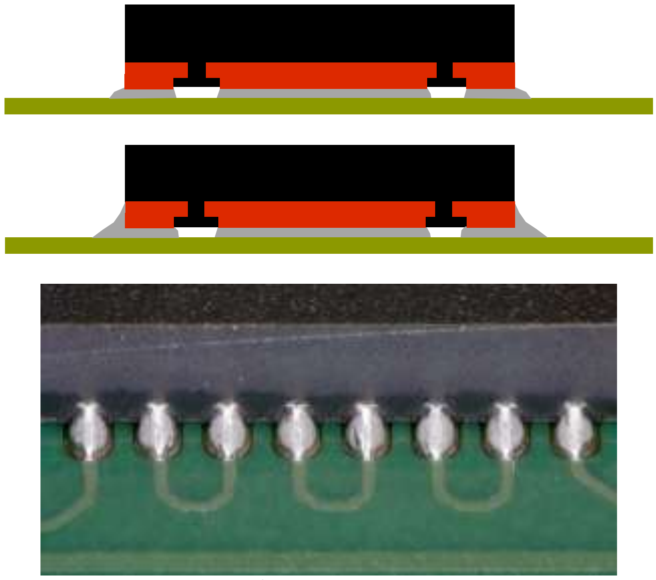


Fig. 1. Soldering miniscus of standard QFN (top) and QFN with wettable flanks (middle). Board mounted QFN with wettable flanks (bottom).

III. RESULTS AND DISCUSSION

Current customer requirement stipulates the existence of a visually detectable solder fillet on package edges indicative of excellent solderability of package on board. Several strategies were explored to realize the challenge including step-cut configuration, wherein the recess created by the step-cut process promotes higher solder volume and increases the solder-wettable surface area. Achieving the step-cut configuration poses a challenge due to the large variability in cut depth (Fig. 2) originating from variations in the input parameters such as the tolerance of half etch location and width, tolerance of blade thickness, machine tolerance for blade path alignment, strip camber, coil set and crossbow maximum specification, machine chuck table planarity, and strip warpage [9]. Therefore, a novel and non-conventional strategy is needed to accomplish the goal of producing partial-cut QFNs, a precursor in attaining the visually detectable solder fillet on package edges.

Laser ablation is a mature and robust technology utilized in several scientific, technological and industrial processes [7,10]. The process utilizes a laser beam focused on a sample surface to remove material from the irradiated zone. Materials absorbing the laser energy could be evaporated or sublimated (low flux), or could be converted to plasma (high flux). The tremendous advances in laser technology has produced versatile laser ablation processes by providing lasers with

Ernesto Antilano Jr. and Ian Harvey Arellano, "Ultra-Short Pulsed Laser Ablation of Epoxy Mold Compound or Copper Frames for Partial Cut QFNs," *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 123-125, 2019.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

varying power, flux, pulsed rates and other customized features. Herein, we present and discuss how laser ablation process using ultra-short pulsed laser could be explored to achieve a step-cut package design by demonstrating laser ablation in epoxy mold compound (EMC) and copper frames in QFN packages (Fig. 3).

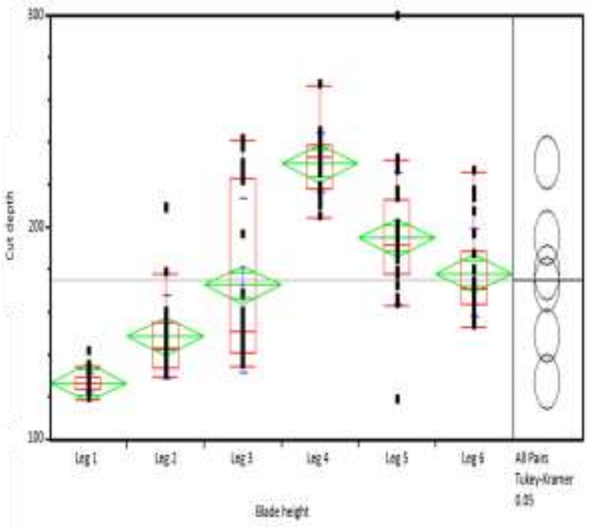


Fig. 2. Cut depth variation after conventional singulation.

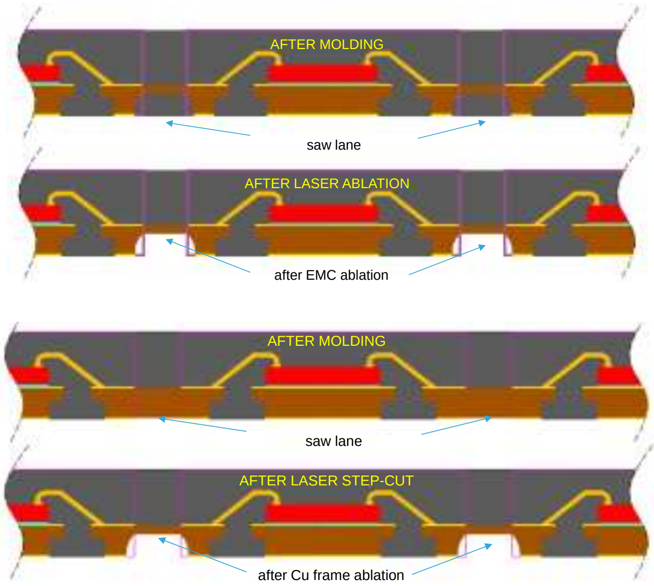
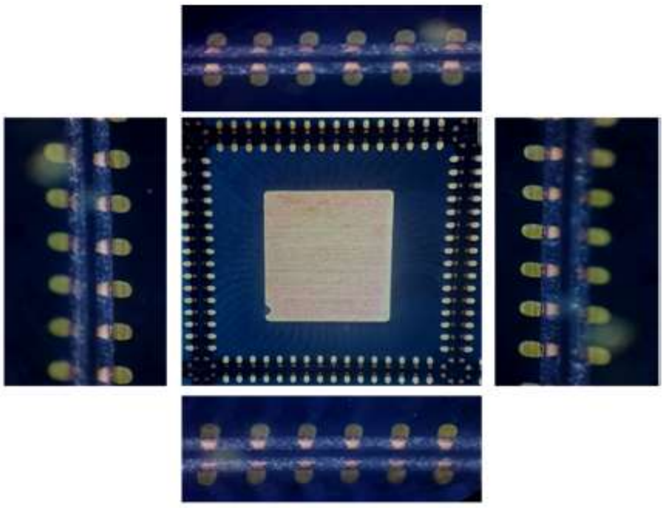


Fig. 3. Laser ablation of EMC (top) and Cu frame (below) to achieve step-cut QFN configuration.

By utilizing a lead design that is partially offset from the package outline edge (*e.g*. pull-back leads or partially etched), it is possible to achieve a partial-cut package configuration. During the QFN assembly process, the leadframe recesses are filled at the molding process. The cured EMC is then removed via laser ablation resulting in the exposition of the flank on leads (Fig. 4). Residual resins and fillers were successfully removed using chemical deflash and high pressure waterjet.



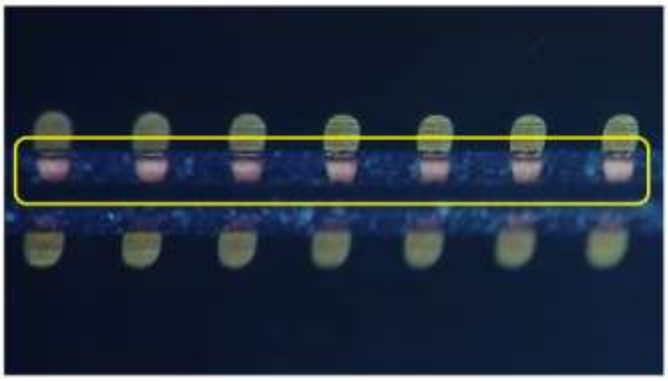


Fig. 4. Laser ablation of EMC resulting in step-cut configuration.

Results clearly show that laser ablation of EMC is a promising strategy to realize step-cut QFN configuration.

It is also possible that instead of removing the EMC, the cut is made via laser ablation of the Cu frame. By using a laser with a lasing capacity enough to vaporize Cu material, standard QFN frame design, *i.e.*, no pull-back leads, could be used to achieve the same result. In this case, wide trench cut or two parallel narrow trench cuts could be made to expose the flank on leads (Fig. 5). The latter was explored to improve the cycle time of the process, wherein instead of cutting through the entire width of the saw lane, narrow trenches enough to expose the sidewalls are made. Nonetheless, both cutting configurations successfully achieved the step-cut geometry of the package. Moreover, no heat-affected zones (HAZ) were observed due to the ultra-short laser pulses used in these evaluations. These results highlight the potential of laser ablation of Cu frames in achieving the desired geometry in QFN packages, and by extension the possibility of achieving visually detectable solder fillet on package edges.

IV. Conclusion

Laser ablation of epoxy molding compound or Cu frame was successfully attained using ultra-short pulsed laser technology. The partial cut geometry achieved in this process brick enables the exposition of the sidewall, which could be plated to create a wettable sidewall, thereby satisfying the customer requirement for visually detectable solder joints for high reliability applications.

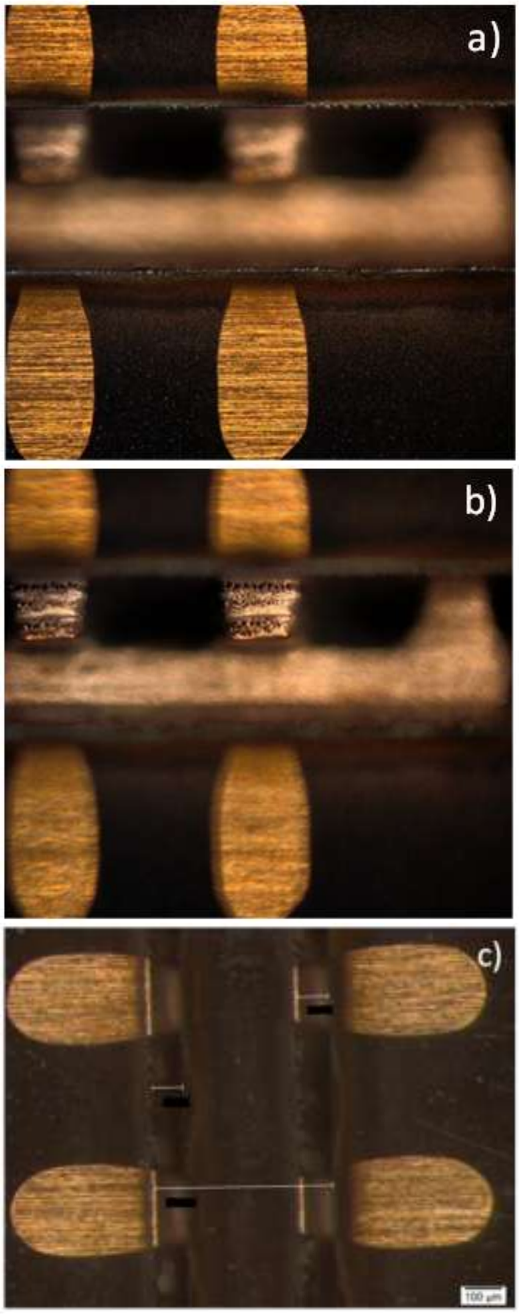


Fig. 5. Laser ablation of Cu frame with a-b) wide trench and c) two parallel narrow trenches resulting in step-cut configuration. b) Tilted view showing sidewalls with no heat affected zone (HAZ).

ACKNOWLEDGMENT

The authors acknowledge the outstanding support of the laser system OEM in exploring their ultra-short pulsed laser technology to create the wettable QFN. We also acknowledge the support of the End of Line group of the New Product Introduction and Assembly Manufacturing departments.

REFERENCES

[1] Ganjei, J. Improved QFN Reliability by flank tin plating process after singulation. *Microsystems, Packaging, Assembly and Circuits Technology Conference (IMPACT)*, 2015 10th International, Taipei, 2015, 137-140.
[2] Barthelmes, J., Kok, S. W., Neoh, D. G., Kurtz, O. Highly efficient corrosion protection for plated pure tin surfaces. *Electronic Manufacturing Technology Symposium (IEMT)*, 2008 33rd IEEE/CPMT International, Penang, 2008, 1-4.
[3] Chuang, C.L., Aoh, J.N., Din, R.F. Oxidation of copper pads and its influence on the quality of Au/Cu bonds during thermosonic wire bonding process. *Microelectron. Reliab. 2006*, 46, 449-458.
[4] Berthold, T., Benstetter, G., Frammelsberger, W., Rodriguez, R., Nafria, M. Nanoscale characterization of copper oxide films by Kelvin Probe Force Microscop. *Thin Solid Films*, 2015, 584, 310-315.
[5] Özkök, M., Mertens, H., Bender, J., Bruder, M. Forming solder filet on leadframe edges of a QFN with immersion tin. *Electronics Packaging Technology Conference (EPTC 2013)*, 2013 IEEE 15th, Singapore, 2013, 677-680.
[6] Cadot, G.B.J., Axinte, D.A., Billingham, J. Continuous trench, pulsed laser ablation for micro-machining applications. *Int. J. Mach. Tool Manu.* 2016, 107, 8-20.
[7] Dubey, A.K., Yadava, V. Laser beam machining-A review. *Int. J. Mach. Tool Manu*. 2008, 48, 609-628.
[8] Hernandez, E., Alfano, M. Lubineau, G. Buttner, U. Improving adhesion of copper/epoxy joints by pulsed laser ablation. *Int. J. Adhes. Adhes.*, 2016, 64, 23-32.
[9] Li, C.-H., Tsai, M.-J., Yang, C.-D. Study of optimal laser parameters for cutting QFN packages by Taguchi's matrix method. *Optics Laser Technol.*, 2007, 39, 786-795.
[10] Sartinska, L.L., Barchikovski, S., Wagenda, N., Rud, B.M., Timofeeva, I.I. Laser induced modification of surface structures. *Appl. Surf. Sci.*, 2007, 253, 4295-4299.