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# Frictional Heating-induced Solder Melting during Singulation in Wettable QFNs

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***Abstract***— *Satisfying the customer requirement of visually detectable solder joints for high reliability application necessitates the development of novel technologies such as the wettable flank technology. One approach involves the exposition of the sidewall via partial-cut mechanical singulation, where the exposed surface could be made wettable through tin (Sn) electroplating process. Herein, we present a failure mode encountered in realizing the wettable quad flat no leads (QFN) package; the molten solder during singulation. Parametric optimization at package singulation revealed that the root cause of the molten solder is the heat generated due to the friction between the singulation blade and the metal sidewall. Complete resolution of the problem was achieved by reducing the feed speed resulting in less friction between the materials, and therefore less heat exposure for the plated solder layer.*

***Keywords***— *Solder, singulation, QFN, friction, solderability.*

## I. Introduction

Quad flat no-leads (QFN) package contains terminations on the package underside preventing the visually detectable solderable terminations when mounted on board. Copper (Cu) terminations located at the package edges, exposed after singulation, are non-solderable due to the thermodynamically driven copper oxidation at ambient conditions, limiting the applicability of the optical or the X-ray inspection to assess the effectivity of the soldering process [1-3]. Electrical testing acts as a check for full electrical connectivity along the soldered interfaces. However, there are design limitations that make electrical testing difficult, in addition to the high cost of test hardware and program necessary for its full implementation. Automotive customers are requiring robust solutions with visually detectable termination solder joint for their high reliability applications (Fig. 1) such as the wettable flank technology, wherein copper terminations at the package edges are solder-plated to prevent oxidation and promote solder joint formation.

Cu sidewalls oxidized instantaneously upon exposure to ambient environment during package singulation. Oxidized sidewalls solder inconsistently, imposing 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) [1]. These wettable flanks allow the solder to form fillets, which can be detected via optical inspection, and are indicative of good electrical connectivity.

The exposed Cu sidewalls require a plating layer that is resistant to oxidation such as Sn, NiPdAu or NiAu [4,5]. In the case of Sn plating, electrical connectivity between packages is required such that a continuous current path could be established, prompting the electro-reduction of $Sn^{2+}$ ions to form a metallurgical layer of $Sn^{0}$. Conventional full cut singulation isolates one unit from another, preventing the electroplating of the sidewall after exposure. Therefore, to maintain electrical connection, partial-cut singulation was performed (Fig. 2), exposing 50-75% of the Cu sidewall height while retaining 25-50% for electrical connectivity, which when electroplated resulted in Sn-plated sidewalls (with plating thickness of 4-8 μm) and Sn-plated bottom pad and leads (with plating thickness of 7-12 μm) [1]. After Sn electroplating, the units are fully isolated via full cut singulation process.

Herein, we report the identification and resolution of a failure mode encountered during full cut singulation process wherein the solder is melting due to the heat generated by the mechanical abrasion of the singulation blade and the material sidewall being cut. The heat is enough to cause melting of the solder-plated layer, which induces functional failure. Resolution of the problem was achieved by reducing the blade feed speed, effectively reducing the friction and the heat generated, thereby eliminating the failure mode.

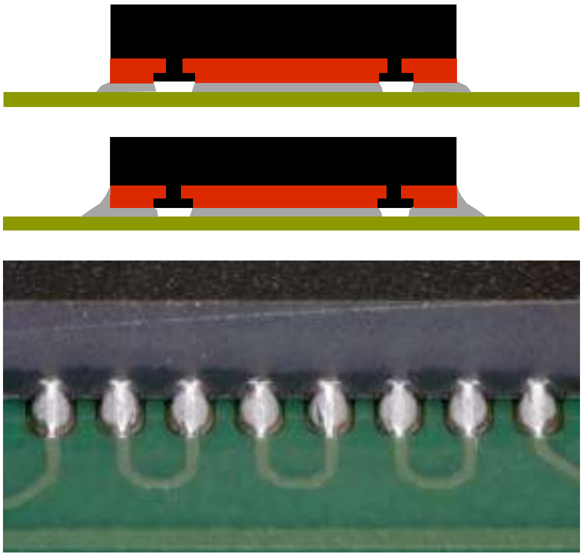

Fig. 1. Soldering meniscus of standard QFN (top) and QFN with wettable flanks (middle). Board mounted QFN with wettable flanks (bottom) [1].

## 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 wire, and



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encapsulating the package using an epoxy molding compound. The partial- and full-cut were realized using a commercially available DFD6362HC (NLA219) DISCO Fully Automatic Dicing Saw with LSD. The electroplating process was performed using Stannopure 100 plating chemistry from Atotech. The effects of the combination of feed speed along the *x*- and *y*-directions, the current and the curing conditions were elucidated using the matrix in Table I. Solderability test was performed following the JEDEC standard (JESD22-B102E) to check the robustness of the solution.

TABLE I. Parametric optimization matrix.

| Leg | Current, A | Feed speed, mm/s | | Curing |
|---|---|---|---|---|
| | | along *x*-axis | along *y*-axis | |
| 1 | 75 | 30 | 30 | UV |
| 2 | 75 | 30 | 30 | no UV |
| 3 | 80 | 30 | 30 | UV |
| 4 | 80 | 30 | 30 | no UV |
| 5 | 85 | 30 | 30 | UV |
| 6 | 85 | 30 | 30 | no UV |
| 7 | 90 | 20 | 30 | UV |
| 8 | 90 | 20 | 20 | UV |

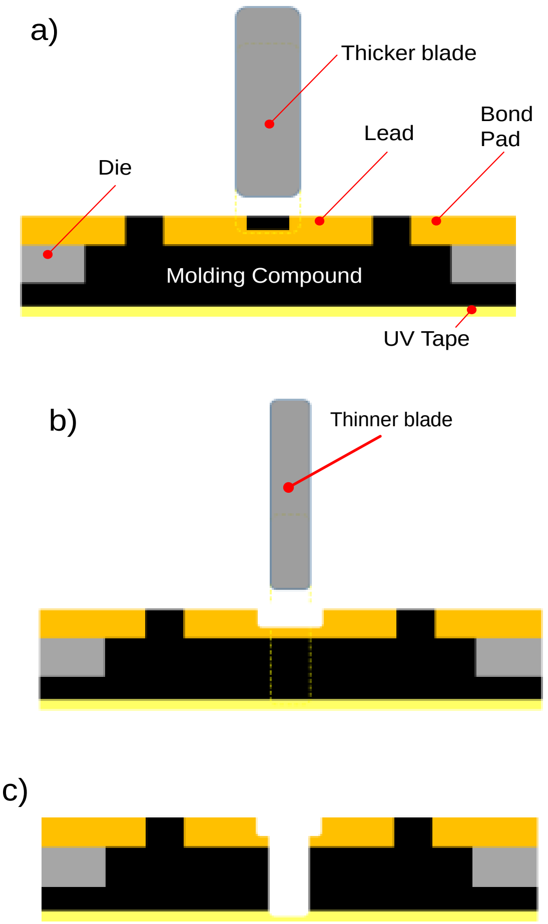


Fig. 2. a) Partial- and b) full-cut singulation schematics. c) Final POD after full-cut [1].

## III. Results and Discussion

The optical image of a QFN package with wettable flank is shown in Fig. 3, where the yellow lines indicate the visible step cut. These solder-plated visible step cut will allow the formation of solder fillets when mounted on board, enabling solder quality check via optical inspection. The partial-cut depth profile shown in Fig. 4 indicate a cut depth of 139 µm, well within the 100-150 µm requirement.

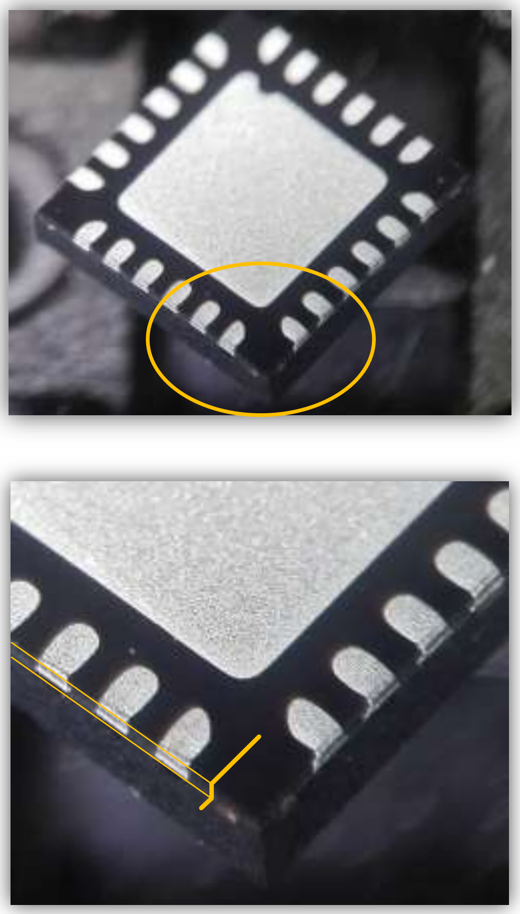

Fig. 3. Wettable flank QFN with visible step cut.

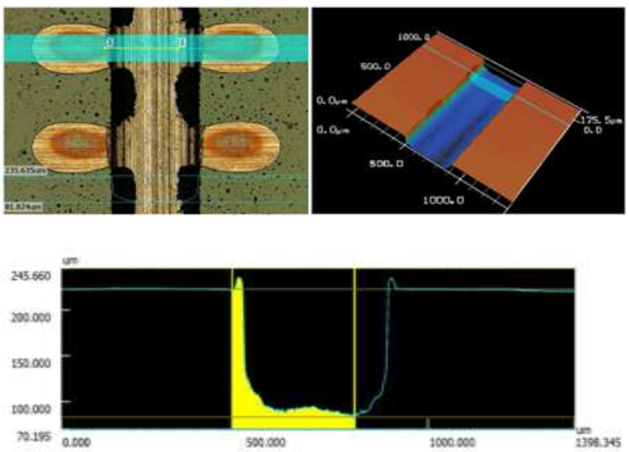


Fig. 4. Partial-cut depth profile.

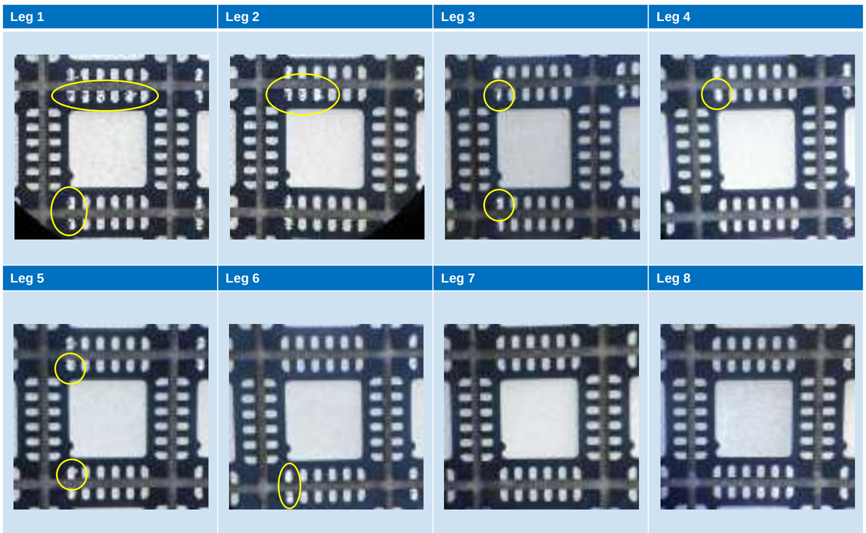


Fig. 5. Representative optical images of the results of the parametric optimization matrix. Molten solder is denoted by the yellow enclosure.

Molten solder was observed in several legs of the parametric optimization matrix as shown in Fig. 5. It can be seen that the occurrence of the molten solder is affected by the current and feed speed used during singulation, but is invariant to the UV treatment. Low current and high speed settings result in molten solder due to the frictional heating. Frictional heating and the resulting contact temperatures have an important influence on the tribological behavior and failure of sliding components [6]. Surface and near-surface temperatures can become high enough to cause changes in the structure and properties of the sliding materials, oxidation of the surface, and possibly even melting of the contacting solids. Metallic components can have contact temperatures which are sufficiently high to melt the sliding surfaces within the real area of contact if the sliding speeds are high enough [7]. By reducing the speed and increasing the current, the frictional heating was effectively reduced resulting in the elimination of the molten solder on leads. Solderability tests of units without molten solder shows 100% solder coverage (Fig. 6), thereby passing this required functional test.

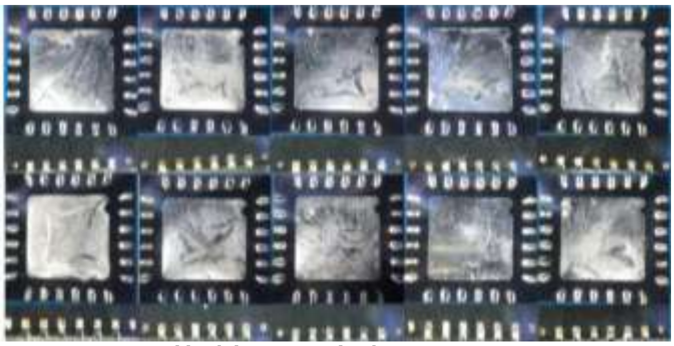

Fig. 6. Solderability test results showing 100% coverage.

## IV. Conclusion

The development of wettable flank QFN relied on the partial- and full-cut mechanical singulation processes, and Sn electroplating process. The occurrence of molten solder on leads during simulation was attributed to the frictional heating due to the sliding surfaces of the sidewall and the singulation blade. By reducing the feed speed and increasing the current, the failure mode was completely eliminated, validating the mechanism of frictional heating-induced solder melting.

## Acknowledgment

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## References

[1] Cabading, P., Malabanan, S., Llana, F.A., Garcia, L., Arellano, I.H. Systematic approach in testing the viability of mechanical partial-cut singulation process towards tin-plateable sidewalls for wettable flank on automotive QFN technology. *2016 IEEE 18th Electronics Packaging Technology Conference (EPTC)*, Singapore, 2016, 254-258.

[2] 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.

[3] 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.

[4] 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.

[5] 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.

[6] Carignan, F.J. and Rabinowicz, E., Friction and wear at high sliding speeds, *ASLE Trans.*, 1980, 24, 451-459.

[7] Furey, M.J. Surface temperatures in sliding contact, *ASLE Trans.*, 1964, 7, 133-146.