Side Wettable Flanks for Leadless Automotive Packaging

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Abstract

The *Micro*LeadFrame® (MLF®)/Quad Flat No-Lead (QFN) packaging solution is extremely popular in the semiconductor industry. It is used in applications ranging from consumer electronics and communications to those requiring high reliability performance, such as the automotive industry. The wide acceptance of this packaging design is primarily due to its flexible form factors, size, scalability and thermal dissipation capabilities. The adaptation and acceptance of MLF/QFN packages in automotive high reliability applications has led to the development of materials and processes that have extended its capabilities to meet the performance and quality requirements. One of process developments that is enabling the success of the MLF/QFN within the automotive industry has been the innovation of *side wettable flanks* that provide the capability to inspect the package lead to printed circuit board (PCB) interfaces for reliable solder joints. Traditionally, through-board X-ray was the accepted method for detecting reliable solder joints for leadless packages. However, as PBC layer counts and routing complexities have increased, this method to detect well-formed solder fillets has proven ineffective and incapable of meeting the inspection requirements. To support increased reliability and more accurate inspection of the leadless package solder joints, processes to form side-wettable flanks have been developed. These processes enable the formation of solder fillets that are detectable using state-of-the-art automated optical inspection (AOI) equipment, providing increased throughput for the surface mount technology (SMT) processes and improved quality as well.

Keywords

Inspect; MLF; QFN; Side Wettable; Solder Fillets, Reliability

I. Introduction

The accelerated growth and evolutionary integration of semiconductor content into the challenging automotive applications has resulted in need for smaller and smaller semiconductor packaging solutions. Leadless packages, such as the *Micro*LeadFrame® (MLF®)/Quad Flat No-Lead (QFN), are desirable as packaging solutions to meet the space saving, size limitation needs of the printed circuit board (PCB) designs. However, as the leads for this packaging format are not externally visible beyond the edge of the package, these devices present a challenge for solder joint validation during post surface mount technology (SMT) processing. Currently, the inspection methods utilized to ensure the package is reliably attached to the PCB are backside PCB X-RAY or a labor-intensive manual optical inspection.

Leaded devices such as the Quad Flat Pack (QFP) or Small Outline Integrated Circuit (SOIC) have leads that protrude enabling the formation of an inspectable solder joint, detectable by automated optical inspection (AOI) vision equipment. In some cases, standard format MLF/QFN devices are inspected using AOI as well. These devices may be of any body size but, most commonly are small body devices (3 mm x 3 mm or less), of low lead count (<16-leads/package) and are found on PCB's that are not densely populated. For solder joint validation, having a visible and detectable fillet is required. How the fillet is formed is less of a concern, as long as it is consistently detectable by the methods used during the SMT post inspections (see Figure 1).

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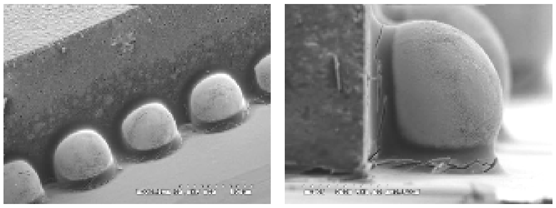


a. b.

Figure 1 | Saw format QFN depicting fillet formed on standard saw singulated lead.

(a) Side view of saw MLF with no enhancement feature for forming wettable flanks
(b) Profile depicting consistency of solder fillet – note coverage of end of lead

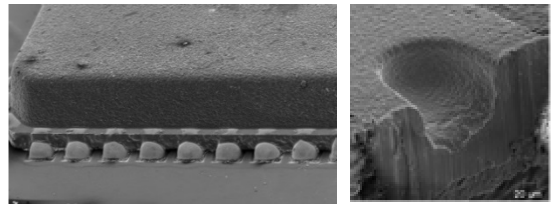
In automotive applications requiring higher lead count solutions or for MLF/QFN devices utilized in safety or mission critical applications, the need for consistent fillet formation, detectable using high speed automated optical inspection is now the automotive industry's stated requirement. There are multiple ways to meet this requirement depending upon the package lead pitch and the package format used in the application.

II. PUNCH DIMPLE WETTABLE FLANKS

MLF/QFN devices are available in both punch and saw formats. To enable the formation of inspectable wettable flanks, innovated technology for enabling consistent lead fillet formation is required. Widely used in the automotive market today is the punch MLF/QFN format, which employs the use of an etched dimple in the leadframe for enabling the formation of a solder fillet on the device leads. There are multiple advantages to this approach that continue to popularize this solution for automotive applications requiring wettable flanks

One important consideration is that since the dimple is formed during the leadframe manufacturing process, the cost impact for enabling wettable flanks for the punch MLF/QFN is very cost effective. Further, the ability to maintain consistency of the dimple dimensions is greatly improved as the process to form it is a specified and controlled as an extension of the leadframe design and etch process. As a result, fillet height formation is predictable and is readily compliant to meet the automotive PCB AOI equipment requirements.

The punch dimple wettable flank is the original solution for fillet formation and continues to be readily accepted today within the automotive industry (see Figure 2), Since the dimple is formed during the leadframe etching process, the tolerances for the dimple width and depth are well controlled, thus enabling a predictable fillet height during PCB reflow.

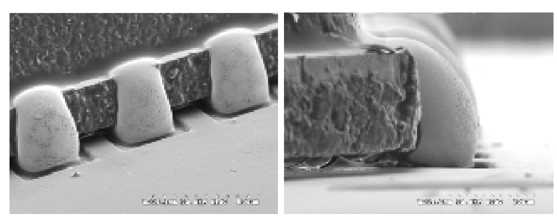


a. b.

Figure 2 | Etched dimple for punch MLF/QFN package format.
(a) 0.5-mm pitch punch device soldered to PCB
(b) Magnified view of etched dimple

The dimple depth is specified with a nominal depth of 100 µm. Leadframe etching techniques ensure that this depth achieves a Cpk=1.67 and is sustainable during the etch manufacturing process. The subsequent solder fillet formation occurring during SMT PCB reflow then can also be maintained at a Cpk = 1.67, thus meeting the requirements of the automotive customers and meeting the capability of the AOI equipment used during SMT PCB inspection processes.

In practice, a typical SMT PCB reflow process using an MLF punch device with dimple, can achieve a fillet height of >100 µm. As depicted in Figure 3, the dimple enables consistent fillet height formation capable of equaling the leadframe thickness. As will be discussed in another section, there are



a. b.

Figure 3 | Punch MLF device with dimple feature applied to the leadframe design.

(a) Plurality of leads, 0.5mm pitch with fillet formation of equal to leadframe thickness (200µm) depicted
(b) Side view of solder fillet formation using punch dimple format

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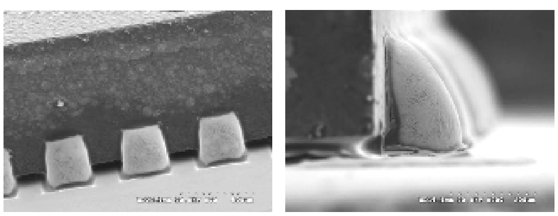
other critical factors to be considered for obtaining the desired fillet height formation. The solder mark thickness, type of solder, solder flux and reflow profiles are critical considerations for fillet height formation, without additional leadframe design and enhancement features, such as the etched dimple

III. SAW DIMPLE WETTABLE FLANKS

For saw MLF/QFN and even dual-flat no-leads (DFN) devices with lead pitch of ≥1.0 mm, the leadframe etched dimple can be successfully utilized as an enhancement feature for the formation of wettable flanks. The same leadframe design modification as discussed early for punch MLF, is utilized in this case. The formation of the solder fillets occurs in the same manner as with the punch MLF devices. The benefits of this solution are the same as with the punch format plus the added benefit of not altering the leadframe density that is typically required for other enhancement feature processes such as saw step cut. By including the dimple in the designs for devices that meet the lead pitch criteria, the wettable flank fillets formation is very similar to that as seen with the punch format. The lead tips are typically completed encased by the fillet and can be formed with shorted solder mask openings, keeping the fillets closer to the side-wall of the device (see Figure 4).

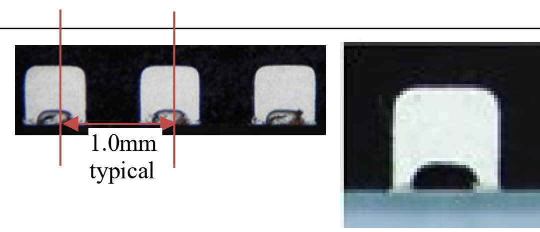


a. b.

Figure 4 | Depiction of wettable flank for saw MLF formed with etched dimple enhancement feature.

(a) Plurality of leads, 0.5-mm pitch with fillet formation of equal to leadframe thickness (200 µm) depicted
(b) Side view of solder fillet for saw MLF with dimple enhancement – note fillet profile

As mentioned, the use of the saw dimple design for wettable flanks is limited to devices with lead pitch of ≥1.0 mm. It is well known that burrs are produced during the saw singulation process. For standard MLF devices, this is typically not a problem but, in the case of the saw dimple design, these burrs are prone to accumulate in the dimple during the saw processes. If the accumulation is sufficient and the burrs not removed, there is a possibility the burrs could impact the solder joint reliability of the device. Fine pitch MLF/QFN/DFN devices with lead pitches ≤1.0 mm, are especially susceptible to burr accumulation in the dimple due to saw feed rate and blade RPM rotation. Removing these burrs is difficult, time consuming, and costly, resulting in not using this technology enhancement for fine pitch devices. However, it is widely used for low lead count devices such as the 3 mm x 3 mm – 12 lead automotive sensor device shown in Figure 5. In these low lead count, wide lead pitch devices, burr accumulation in the dimple area is negatable, and any that does collect can be effectively remove by approved cleaning techniques. Considering the lead spacing of ≥1.0 mm, metal smear that may occur during device singulation is maintained to meet the requirement of >50% of lead pitch. Metal spear and burrs will be covered in more detail in a following section.



a. b.

Figure 5 | 3 mm x 3 mm – 12 lead, 1.0 mm pitch saw MLF with dimple enhancement.

(a) Side view of device depicting the leads with dimple profile visible
(b) Close up of lead with dimple enhancement – note no burrs and no metal smear

IV. SAW STEP CUT WETTABLE FLANKS

To enable wettable flanks for MLF/QFN/DFN devices with lead pitch of ≤1.0 mm, a process is required that can minimize the effects of burrs and metal smear generated during the saw singulation process. Several different technology approaches have been proposed and/or tried with the current industry accepted solution know as step-cut being the most widely utilized (see Figure 6).

Unlike the punch and saw dimple solution for wettable flanks, the saw step cut requires specialized singulation equipment, leadframe design modification and additional assembly manufacturing processes. As a result, the saw step cut process increases the manufacturing process complexity and increases assembly cost. The primary difference in the

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standard saw process for saw MLF and step cut is that in the case of step cut, two saw steps are required in the manufacturing process flow to form the wettable flank (see Figure 7).

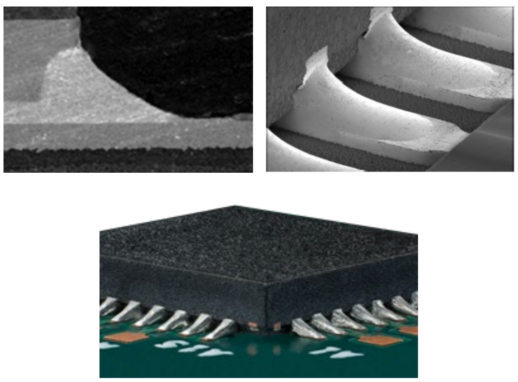

Figure 6 | saw MLF depicting solder fillet.

Shown is a 5 mm x 5 mm, 32-lead. 0.5mm pitch device mounted to a BLR test board.

The basic process for saw step cut is the same as the standard saw singulation process, modified by the addition of an addition saw process prior to plating. Unlike the punch process, saw singulation creates debris that if not controlled may have multiple impacts on the solder joint integrity, e.g. solder voids, standoff inconsistencies and tin (Sn) plating issues. To mitigate these risks, the leadframe design is modified to alter the saw street, special saw blades are utilized and custom saw singulation jigs are designed and

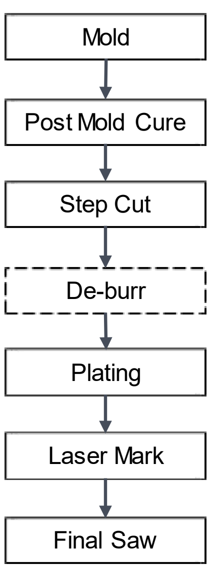

Figure 7 | Generic Step Cut Process Flow

(Note the optional de-burr process step)

implemented. In very fine pitch device designs, ≤0.5 mm, the use of a chemical de-burr process may also be required to remove the debris prior to plating thus minimizing any solder joint integrity issues that might otherwise result during the PCB assembly process.

The saw step cut is effective for enabling the formation of a fillet suitable for AOI detection, post SMT PCB assembly. However, in order to ensure the fillet formation can achieve the required Cpk = 1.67 performance, special process controls and saw tooling must be employed to maintain leadframe planarity and alignment during the first and second saw operations. These process controls and tooling enhancements also ensure that the step alignment and tolerances on each side the cut are within specification (see Figure 8).

Similar to the other techniques described, the fundamental goal with the saw step cut process is to enable the formation of a fillet on the MLF/QFN/DFN leads during PCB solder reflow for purposes of AOI. The desired fillet height to meet the AOI requirement is the same as for the other methods, ≥100 µm. This is possible as long as a leadframe thickness of 200 µm is used. For thinner devices, which require thinner leadframes, the fillet height capability will decrease. As an example, an MLF/QFN/DFN device using a leadframe thickens of 150 µm, is capable of supporting a maximum step cut depth of 75-80 µm, thus enabling a fillet height of ≥80 µm to 85 µm maintaining a Cpk = 1.67.

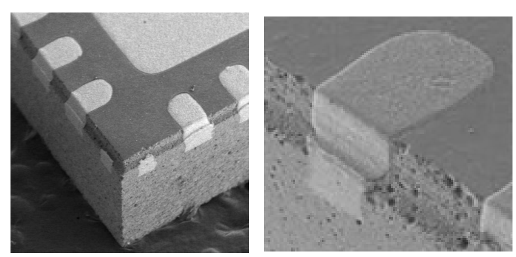

Figure 8 | MLF with step cut feature.

Consistency of step cut width is maintain by leadframe design and saw jig used during first and second cuts. Wide variation may result in no step on one side of a device and too much on the adjacent device in the leadframe array.

A key advantage to the saw step cut process for enabling wettable flanks is its flexibility of application to the MLF/QFN/DFN body size variations. Device body sizes ranging from 2 mm x 2 mm to 12 mm x 12 mm, including rectangular and incremental sizes in between, are suitable for applying the step cut process. As the MLF/QFN/DFN packaging technologies utilize a MAP array leadframe configuration, the step cut process can be applied with minimal tooling modifications for the various body sizes.

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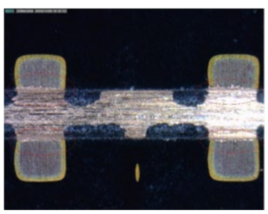
This is especially important for small body devices >3 mm x 3 mm, where the punch format is not typically supported.

The biggest challenge in the saw step cut process is controlling the burr generation and metal smear during the singulation steps. As depicted in Figure 7, the use of a chemical deburr process can be effectively utilized to mitigate the issues. In device lead pitches ≥0.5-mm pitch, as long as the saw process parameters and the saw blades are properly maintained, the deburr process is not typically needed or employed. However, for devices <0.5-mm pitch, the chemical deburr process is of significant benefit especially in minimizing the impact of metal smear (see Figure 9). The benefits of using a chemical deburr process are also seen for devices < 0.55-mm thick. In the case of these thinner packages, the saw singulation feed rate is typically lowered and as a result, the metal smear and debris generation tend to increase. Other techniques such as a finer grit saw blade may be applied instead of chemical deburring but the effectiveness in removing the debris and metal smear is less, plus these other techniques are typically not as cost effective and often lead to process yield issues.



First cut, before chemical deburr

First cut, after chemical deburr

Figure 9 | Effects of chemical deburr in removing burrs and metal smear (50-sec bath example).

V. CHOOSING THE BEST OPTION

As discussed, there are multiple wettable flack options to choose from and all will enable the solder fillet required for automotive AOI post-PCB assembly. The key factors for consideration when deciding the best solution for any device are: (1) automotive application requirements; (2) device package design requirements; (3) manufacturing limitations; (4) automotive Tier 1 requirements; and (5) cost of implementation.

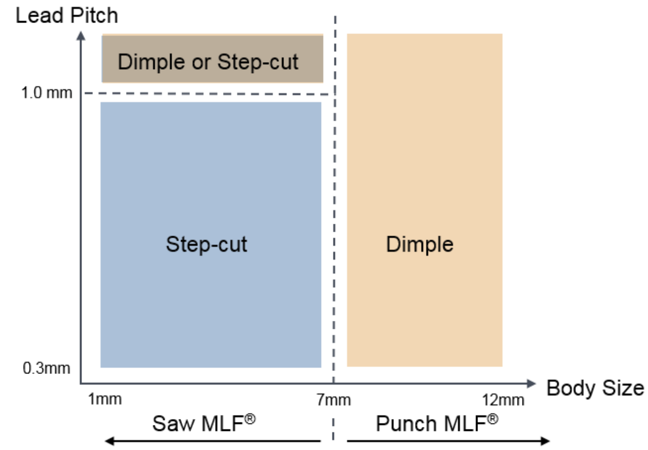


Figure 10 | Attributes for wettable flanks selection.

These five attributes are delineated in a simple graph form depicted in Figure 10. As noted, the device body size may be considered the primary or starting point in the decision process. As indicated, for MLF body sizes ≥ 7 mm x 7 mm, it is recommended to select the punch MLF package format. As previously reviewed, the punch dimple, formed during the leadframe manufacturing process, results in the most cost-effective solution for enabling wettable flanks, making it the best choice for large body devices.

The other key attribute for consideration in this simple decision tree is the lead pitch. As noted in Figure 10, for lead pitch ≥ 1.0 mm, the recommendation for the package format is based more on design requirements/needs, customer preference and format availability. In this case, where the lead pitch is ≥ 1.0 mm, then the leadframe dimple, punch or saw package format is the best choice for enabling the wettable flank.

For devices with lead pitch ≤ 1.0 mm and device body size requirements less than 7 mm x 7 mm, the recommended solution for enabling wettable flanks is noted as saw step cut. There is little doubt that step cut is the preferred solution for device body sizes < 3 mm x 3 mm due to lack of availability of the punch format in these body sizes. Within this body size grouping is the DFN devices and the majority custom device body size requirements (see Figure 11).

Given the cost effectiveness of the MLF mold array process (MAP) leadframe design, for small body MLF and DFN packages (<3 mm x 3 mm) the saw step cut is considered the industry choice for meeting the automotive AOI wettable flank requirement for solder fillet formation. There are multiple methods applied by assembly manufactures but, as long as the processes provide the desired results for meeting the fillet height requirement and can successfully enable the post solder reflow AOI verification, then any of the processes

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practiced today are considered acceptable solutions for supporting wettable flanks for fillet formation.

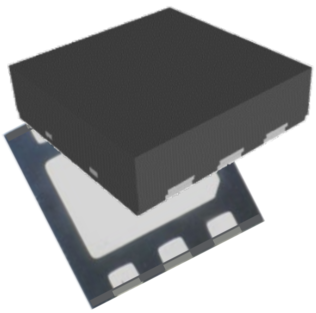

Figure 11 | Depiction of DFN 3 mm x 3 mm. Saw step cut process applied

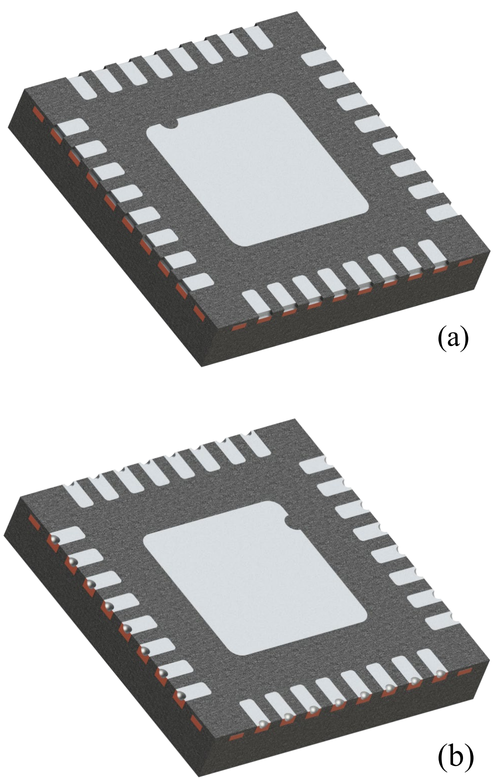

Figure 12 | Saw MLF 5 mm x 5 mm, 32-lead devices.

(a) Device depicting the step cut wettable flank option applied
(b) Device depicting the saw etch dimple wettable flank option applied

VI. BURRS AND METAL SMEAR

All of processes used to modify the lead of an MLF-type device have the potential to create burrs during singulation. The dimple configuration used in the punch process has been carefully designed to be the least impacted by burrs. This is another reason the punch and the dimple solution are popular within the automotive industry. Proper sizing of the dimple to the device lead width is key to maintaining the effectiveness of this option for enabling fillets during the SMT PCB reflow process (see Figure 13).

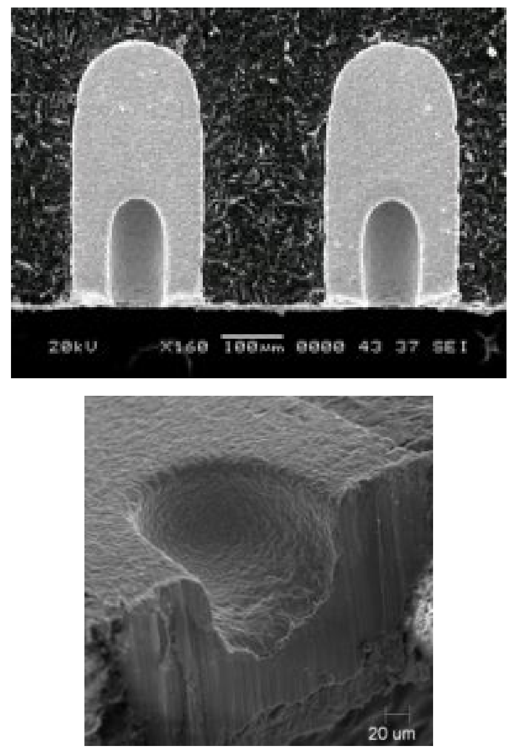

Figure 13 | Punch dimple post singulation and matte Sn plating.

Applying the same dimple concept to a saw MLF process produces different risks for burr and metal smear. Primarily, this is due to the device unit density of the MAP leadframe design and the use of saw singulation. Burr formation and debris accumulation in the dimple during singulation are the two limitations of utilizing the etch dimple for device lead pitch of <1.0 mm.

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Depicted in Figure 14 are the types of burrs and smear that may occur during a typical saw singulation process. Each of these burr types must have a manufacturing specification for process control as well as for Final Visual Inspection (FVI).

Each type of burr may have an impact on solder joint reliability, device seating plane (package tilt) or lead-to-lead shorting. To minimize potential impact of burring during saw singulation, the dimple is sized to the lead width and sized to specifically minimize Z-burr formation and singulation debris accumulation (see Figure 15).

Similar burring issues exist with the formation of the step cut feature. In the process, the Z-burr and metal smear are the primary concerns: Z-burr due to impact to device standoff and tilt during solder reflow and metal smear as the step cut process is predominantly used for fine lead pitch devices (<0.5 mm). To assist in mitigating the effect of the burrs and metal smear, the introduction of a chemical deburr process may be applied. The purpose of this process is to remove the burrs and debris prior to the plating operation, thus improving the robustness of the step cut process.

The effectiveness of the chemical deburr process was highlighted in Figure 9. Figure 16 depicts a 0.5-mm pitch evaluation device that did not go through the chemical deburr process. It is readily apparent that without chemical deburr, devices with fine pitch leads cannot use the saw dimple feature, but, if it is applied, the saw dimple feature should be extended for use with 0.5-mm pitch devices.

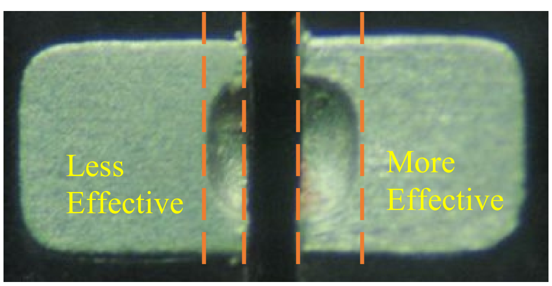
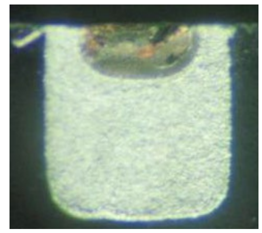


Figure 15 | Etch dimple sized to minimize burr formation during singulation.

(a) Z-burr

Leadframe material accumulation in vertical direction

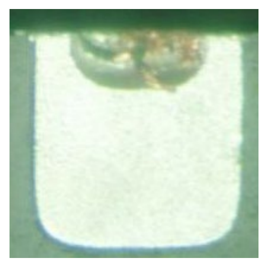


(b) X-burr

Leadframe material accumulation on lead cut line

(c) Smear burr

Leadframe material accumulation, reducing distance between leads



(d) Copper (Cu) burr

Leadframe debris accumulation within the dimple area

Figure 14 | Types if burrs resulting from saw singulation process. Each type has a unique process control specification.

VII. SOLDER FILLET FORMATION

The sole purpose of the wettable flank is to enable the formation of a fillet that can be detected post SMT PCB processing using AOI equipment (see Figure 17). The solder fillet serves as the detection indicator that a leadless device, such as the MLF/QFN/DFN package, has be correctly soldered to the PCB. For the AOI equipment to correctly detect and identify good vs bad solder wetting, the fillet height needs to be maintained at a Cpk = 1.67 consistency. The industry standard for the fillet height to meet the AOI detection capability has been stated to be approximately 100 µm. The actual height requirement is a function of the equipment being employed to do the inspection. Grayscale

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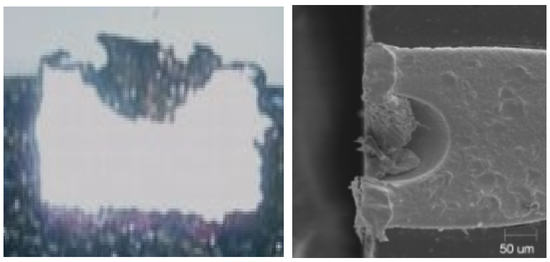
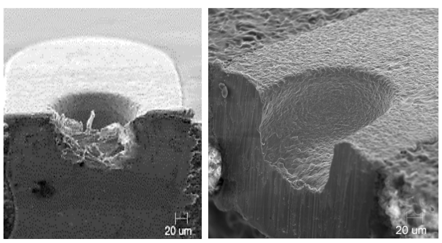
AOI equipment is still widely employed in the automotive SMT PCB inspection process for detecting the fillets of all the wettalbe flanks options reviewed in the context of this paper.



(a) (b)



(c) (d)

Figure 16 | Depiction of etch dimple used with 0.5-mm lead pitch device

(a), (b) & (c) depict the accumulation of Z and X burrs as well as Cu burr accumulation in the dimple area.
(d) depicts the results of applying chemical deburr to dimples used with 0.5mm lead pitch

However, it is noted that for automotive mission critical devices such as sensor and safety applications, AOI equipment with color illumination is being employed to look at the height of the fillet height to further improve the detection and reduction of defect escapes (see Figure 18). The challenge faced for yield improvement and defect escape rates is properly defining what is to be considered a good solder joint using the fillet height as the metric.

The determination of the correct fillet height using the AOI inspection is partially a subjective decision based on equipment capability and PCB assembly process goals. Since the solder fillet is not a feature intended to improve Board Level Reliability (BLR), unless there is a known or stated concern for BLR performance, the expectation for the AOI detection process should be for high yields with minimal concern for defective solder joints associated the devices identified as good.

For each of the reviewed wettable flank options, there are different manufacturing process aspects to be considered in order to meet the stated industry goal for fillet height of ~100 μm with a process Cpk = 1.67. In the case of the non-enhanced design, the formation of the fillet is dependent upon the PCB solder mask design for the leadless device, stencil design, type of solder and flux used and reflow profile. For the dimple designs and step cut options, these considerations are also of importance for obtaining the desired fillet. In the case of the saw step cut process, there are additional, critical process concerns that must be addressed to achieve the desired fillet formation during PCB reflow.

Figure 17 | Example of PCB AOI with color illumination capability. Nordson FX-940 shown.

Foremost in the list of considerations is controlling the cutting depth during the first saw process. Essential to the sustainability of the first cut process of Cpk = 1.67, the leadframe design and saw singulation tooling and equipment are critical factors. Design features are employed to control and manage warpage. Specialized saw singulation equipment is used to maintain the specified tolerances during the complex cutting process. Since the first cut only singulates the device leads, the use of integrated AOI in the singulation saw equipment has proven to be very beneficial for maintaining alignment accuracy (x-y-z) during the first cut.

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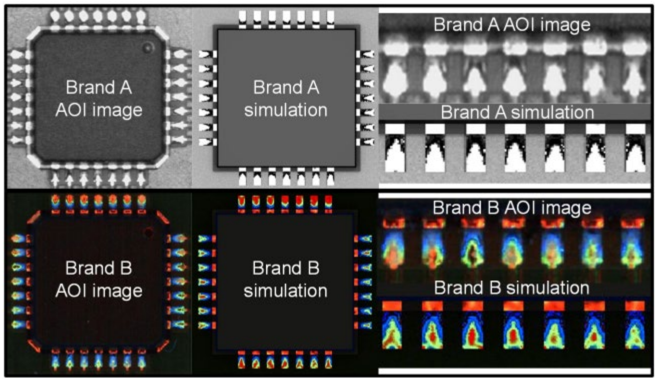

Figure 18 | Depiction of the differences seen in solder fillet inspection when using grayscale AOI equipment and AOI equipment enabled with color illumination.

Of equal importance to forming the step cut during the assembly operation, is employing proper PCB design techniques to ensure the desired fillet formation. Shown in Figure 19 are the PCB design and reflow process parameters developed by Amkor for optimizing the step-cut fillet height for a 5x5, 32 lead, 0.5-mm pitch device.

The PCB solder land design was varied at three different lengths and widths. The solder land extension was varied to determine how the solder fillet forms relative to the land length.

Some variation was detected during the development of the optimized parameters but, for all cases, the fillet height formed was measured to be > 100 µm, with a Cpk ≥ 1.67. Results of the testing are shown in Table 1.

Important to note in the fillet height formation is where the fillet height is measured (Refer to the depiction in Figure 20.) Fillet height must be measured from the PCB to the crest of the fillet. As result of this study, it has determined that by using a step cut with a minimum of 70-µm cut depth, the variation that may occur in the solder paste thickness applied during the SMT process is compensated. Therefore, a 100-µm fillet, as needed for the AOI used in automotive SMT PCB inspections, will always be achievable.

Commonly accepted is the definition of fillet height being measured as A + B,

where,

A = the PCB solder paste thickness

B = the extended fillet form by the step cut.

With the capability of the Amkor step cut process to provide a fillet height of ≥100 µm with a minimum step cut of 70 µm, the variation of A (typically 30 µm), solder paste thickness on the PCB, can vary as much as 10µm and still have a fillet height of a minimum of 100 µm. This is a significant advantage to the SMT process since it increases the process window for the solder paste application while still ensuring optimal performance for the AOI process when inspecting the solder fillet height (e.g. solder joint formation).

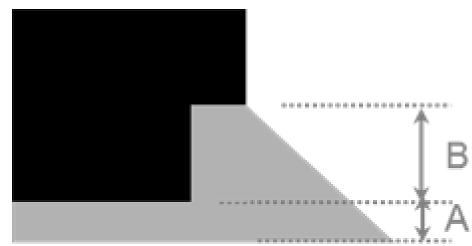

Figure 20 | Fillet defined in conjunction with PCB process applied solder thickness. Fillet height is A + B.

Land Pad Design	# of Samples	Solder Fillet Height (Ave)				
		Test 1	Test 2	Test 3	Test 4	Test 5
600 um	32 each	216.63 um	202.38 um	203.38 um	203.44 um	200.00
400 um	32 each	216.94 um	206.25 um	203.13 um	201.25 um	200.31 um
250 um	32 each	210.38 um	195 um	201.25 um	202.00 um	206.00 um

Table 1 | Fillet heights as a function of solder land variation.

NOTE: Units used in this testing had an average fillet height of 135-µm depth. As a result, the fillet height for all solder land extension was typically >200 µm.

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VIII. CONCLUSIONS

A method for enabling wettable flanks on leadless semiconductor packages such as the MLF/QFN/DFN is desirable to enable AOI during post SMT PCB assembly. Specifically, the automotive industry has indicated this is not just a need but a requirement for all leadless devices, regardless of lead pitch or automotive application. This is primarily driven by the rapid growth of leadless components being designed into automotive applications. Several wettable flank options for leadless packages have been presented and reviewed for effectiveness, suitable attributes for application, sustainability in high volume MLF/QFN/DFN manufacturing and cost of implementation. It has been shown that under optimal conditions, any of these options can enable the fillet formation during PCB solder reflow as required to support and sustain AOI inspection. There are limitations with each option, so multiple solutions are offered within the industry to account for packaging format differences (punch and saw singulation), lead pitch and body size. Each solution potentially may have a different yield and processing rate for the AOI inspection. The impact of these differences is a part of the decision process when deciding which wettable flank solution is best suited for a specific application.

The stated goal of the wettable flank has been and remains to enable AOI. While it may be possible, the fillet formation may have an impact on first fail and potentially increase the mean time between fail, the use of the wettable flank has not been shown to dramatically improve BLR testing. Devices with and without wettable flanks tend to have similar performance during JEDEC standard BLR testing and both types meet expected performance goals.

The importance of proper PCB design, specifically for ensuring the correct solder mark thickness and solder land design are applied for obtaining and sustaining the needed fillet height during SMT PCB reflow has also been reviewed. Once formed, the subjectivity of defining a good fillet height and shape as detectable by AOI has also been highlighted, indicating that the purpose of the wettable flank may be in transition from an indicator of proper solder reflow and board attach to an indicator of the reliability of the solder joints.

While gray scale vision capable AOI is still widely used, the trend seems to be toward AOI equipment capable of color illumination. Selection and utilization of these more expensive and capable AOI systems is considered an industry indicator that the wettable flank and formed fillets are growing in popularity and that the fillet itself is being considered more than an indicator for proper device attachment to the PCB but also may be correlatable to solder joint reliability. The correlation between the two has not yet been fully demonstrated but this association is being investigated by multiple automotive manufactures as well as leadless package assembly providers.

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