Eliminate Costly Component Out Of Pocket Defect Condition during Microelectronic Component Packaging/Shipping/Handling

Rich Rochford, Craig Blanchette
BAE Systems, Electronic Combat Solutions
65 Spit Brook Road
Nashua, NH 03060
Ph: 603-885-4321
Email: Richard.Rochford@baesystems.com | Craig.Blanchette@baesystems.com

Abstract
High value devices used in microwave modules and other microelectronic assemblies have become increasingly thin and susceptible to “Component Out Of Pocket” (COOP) conditions that can occur during packaging, shipping, and customer handling. This defect condition is especially problematic for automated assembly which strives to be touch-free and efficient with orderly device presentation.

COOP is a major contributor to “Cost Of Poor Quality” (COPQ) within the business. A funded study into COOP conditions was conducted and a dozen root causes were identified.

It was discovered that traditional “waffle packs” have mechanical issues related to flatness tolerances with respect to the waffle tray and lid. The addition of a standard clip further contributes to the issue, both of which are key root causes of the costly “Component Out Of Pocket” (COOP) condition.

A novel Lid-Clip System (LCS2) was engineered to compensate for those mechanical issues, bringing robust captivation and preservation of devices in waffle tray pockets. Static dissipative material for lid and clip was selected to provide unparalleled ESD Class 000 protection for high value devices with the lowest voltage susceptibility thresholds.

Key words
Clip, Component, Die, Insert, Lid, Migration, Waffle pack, x-ray

I. Introduction
This paper describes the root causes of the “Component Out Of Pocket” (COOP) (Fig. 1) defect condition in waffle packs that has persisted in the microelectronics industry for decades, complicating the task of achieving zero defects and driving up manufacturing costs. Military aerospace and commercial manufacturers alike, worldwide are incurring unnecessary costs in the form of component damage, component scrap, and the non-value added labor associated with re-ordering scattered components. Once x-ray data was introduced we had sufficient data to reveal the scope of the component migration defect. The opportunity to innovate became apparent.

Microelectronic component suppliers are becoming aware of this pervasive packaging defect which until the advent of a unique x-ray tool in 2017 was escaping detection. This is important because semiconductor devices in particular are in short supply, costly and the additional assembly labor and the equipment down time it forces is a cost driver in manufacturing operations that use components with thickness of 0.010-inch and less. These components are particularly susceptible to this defect condition.

Fig. 1. X-ray showing COOP (“Components Out Of Pocket”) in a fully packaged waffle pack as received from supplier at incoming inspection
II. Characterization / Root Causes

Multiple root causes of COOP defects have been identified (Fig. 2). Many microelectronics industry professionals have failed to recognize the implications of published flatness specifications [1] associated with injection molded trays and lids (i.e., 0.012” carbon loaded polypropylene, 0.004” carbon loaded polycarbonate) (Fig. 3). For a thin GaAs die, that leaves plenty of egress for escape. Consider the tolerance stack up when selecting from standard lids and trays as it could be as high as 0.024” and 0.008” for polypropylene and polycarbonate, respectively. Standard clips also impart deflection of lid and tray material due to the design as shown in (Fig. 4).

For decades, end users and suppliers of components in waffle packs have been pointing fingers, casting blame on one another for migrated components. Keyence VR-3200 3D Scanner [2] was key to visualizing and measuring the flatness tolerances that led to the mechanical issues that cause COOP (Fig. 5). With the advent of an all-important x-ray counter system by VJ Electronix model XQuik II Plus [3] (Fig. 5) developed for BAE Systems in 2017, specifically designed to count components in sealed waffle packs at the receiving inspection level, we have definitively proven that COOP occurs both at supplier sites and during transit, well before end users have the opportunity to open waffle packs.

Principally, flatness tolerances of the various materials used in the manufacture of waffle pack trays and lids were visualized and measured using equipment shown in (Fig 5a, 5b). Semiconductor industry component suppliers are typically unaware they are shipping components out of pocket because few employ x-ray systems to validate the effectiveness of their final packaging operation. While there is plenty of blame to be shared for COOP, including by end users, we now have a clearer understanding of the mechanical issues which top the list of root causes.

Fig. 6 shows dark orange locations A and C on inside of lid that act as standoffs when contacting top of tray thus allowing components to migrate under the blue locations that measure up to a 0.0094” gap.

Another prevalent cause of COOP is the misalignment of loose inserts that leads to pinching of inserts used for the waffle pack assembly process (Fig. 7). One misconception in the industry is that loose inserts prevent COOP however, our research has shown it can actually contribute to it, as when inserts are misaligned or pinched which is frequently the case. Pinched inserts can be evident along edge in between tray and lid.

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**Fig. 2. The Root Causes of COOP Identified**

**Fig. 3. Comparison of Internal Lid Surface Flatness Measured Using Keyence VR-3200 3D Measurement System**

**Fig. 4a. Standard industry clip design**

**Fig. 4b. Side view of standard tray and lid inside clip**

**Fig. 4c. External flatness contour from top down view**

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The risk of device damage is inherent to components when working with loaded waffle packs with that risk amplified for components ≤0.010” thick. The risk of COOP is present when clips are attached and removed, because the lids are essentially unsecured and waffle packs are being tilted to some extent; the lid can pop up on one side when unequal pressure is applied by operator to opposite side of waffle pack. That condition combined with the slightest vibration can cause COOP. It is at this stage of the packing and unpacking process where components are also at significant risk for migration (Fig. 8).

In response to the multiple deficiencies identified in the most commonly used bare die packaging (i.e., waffle pack/chip tray), a novel Lid-Clip Super System (LCS2) was engineered to overcome the 0.004” flatness tolerance inherent to industry standard ABS and polycarbonate trays and lids. Optimal component preservation is ensured through the effective gasketing of each and every tray pocket in order to establish a new industry best practice and a defect free packaging/shipping/handling solution. LCS2 represents an important new option for the mitigation of “COOP”. Our solution is an enhanced lid comprised of low outgassing, static dissipative, low density polyurethane foam and industry-approved interleaf material assembled onto a static dissipative injection molded lid using silicone free pressure sensitive adhesive (Fig 9). This is combined with a novel clip design (Fig 9 and Fig 10) which uniformly compresses the lid around its full top perimeter allowing the elastomeric foam to take up the unevenness due to the warpages of the lid and tray, ensuring intimate contact of the entire interleaf against the top of the warped waffle tray surface.
Static dissipative material for the injection molded lid and clip was selected and tested per ANSI/ESD S11.11 to provide ESD Class 000 protection for high value devices with the lowest voltage susceptibility thresholds.

Efficacy of the Lid-Clip System has been demonstrated through rigorous drop testing of 0.002” GaN devices stored in industry standard carbon loaded polycarbonate waffle tray from 34 inches using x-ray to verify containment or the absence of COOP condition (Fig. 12). Ten unique novel lids and novel clips were tested and dropped a total of 10 times each for 100 total drops with no detected COOP (Fig. 9). When the industry standard 1-piece clip was substituted for the new Super-Clip, COOP occurred (Fig. 12) demonstrating the necessity for the novel clip.

Throughout the journey of finding root causes for COOP and developing a solution this packaging guide became necessary. Given the specific packaging features that are required, this guide compares LCS2 to the four most widely used device packages in the industry. For all its benefits LCS2 has the potential to become the new industry best practice (Fig. 14).

**LCS2 has been very well received by early evaluators citing:**

- Quick and simple assembly process
- No fumbling with inserts
- Easy access to apply lid and tray labels
- Easy access to read and scan lid and tray labels
- Most importantly, the components remain protected in pockets from supplier packaging to the end users pick and place machine

In addition to drop testing, the LCS2 with the 0.002” GaN die were subjected to the extreme vibrations of a Blair Equipment Tornado II [5] paint shaker. This was meant to over exaggerate the conditions that semiconductor components see while on a truck being shipped to end user. The LCS2 was loaded upside down and subjected to 30 seconds of vibration (Fig. 13). The x-ray results revealed no COOP.

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**Packaging Selection Guide**

<table>
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<th>Features</th>
<th>LCM</th>
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<th>AS3</th>
<th>carbon loaded polyimide</th>
<th>carbon loaded polyimide</th>
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<td>COOP Prevention for Devices ≥0.002”</td>
<td>BEST</td>
<td>BEST</td>
<td>LOW RISK</td>
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<td>HIGH-RISK</td>
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*LCS2 IS POSED TO BECOME THE NEW INDUSTRY BEST PRACTICE

*VRP Gel-Pak is available in a silicone-free variant.*

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III. Conclusion

Overall, this novel Lid-Clip Super System solves for the costly “Component Out Of Pocket” condition for all sized components but especially for ultra-thin components ≤0.010” all while continuing to use industry standard waffle packs. This will then eliminate non-value added Supplier Corrective Action Requests/Return Material Authorizations. The Lid-Clip Super System has tremendous potential to curb millions of dollars in waste and improve component process efficiencies worldwide.

Acknowledgment

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References

[1] Entegris website Tray Wizard (entegris.com)
[4] Forgione Engineering, Matteo Forgione