MITIGATING MOLD FLASH ON OVER MOLDED PLASTIC (OMP) PACKAGES THROUGH INTEGRATION OF MECHANICAL BARRIER

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ABSTRACT

Mold flash presents more than cosmetic defects; it degrades mechanical tolerance, jeopardizes solderability, and incurs additional cleaning costs. It poses significant reliability, electrical, mechanical, and assembly challenges.

This research demonstrated that the integration of mechanical barriers mitigates the occurrence of mold flash. Substrate A (substrate without mechanical barrier) and Substrate B (substrate with mechanical barrier) topography were compared via 3D profilometry, which validated the presence of mechanical barrier. This barrier was then quantified and analyzed based on its dimensions as well as its implications on the mold mitigation performance.

Despite the significant height difference that was observed between the sides along the length and along the width of Substrate B, it is evident that mold flashes on substrates without barriers transitioned from heavy flashes on the periphery down to minimal flashes on the corners and edges. The introduction of the mechanical barrier improved yield on post-mold process control from 41.30% to 97.69% and eliminated additional post-mold cleaning process.

1. 0 INTRODUCTION

Over-Molded Packages (OMPs) are staple and widely known types of Integrated Circuits (ICs) that obtained prevalence and popularity over the years. In line with this increasing demand for OMPs, the attention on Epoxy Mold Compound (EMC) has grown as well in which EMCs with varying formulation bloom in semiconductor industry to satisfy different applications. Alongside the popularity of OMPs, EMCs became widely used due to several reasons such as hermiticity, cost-effectiveness and availability. However, despite the benefits that these epoxies for molding provide, inevitably, some disadvantages come with it. One of the most common problems that EMCs encounter is the issue of resin bleeding.

EMC resin bleed happens when the low-viscosity component of the epoxy flows out of the bulk system and seeps onto the unintended surface. This issue poses several risks such as mold tool contamination in which mold debris builds up on mold tool cavities requiring more frequent cleaning. Resin bleeding can also result in cosmetic visual defects due to the stains and bleed marks that are rejectable even if it passes electrical tests.

One more issue that EMC is prone of is the occurrence of mold flashes. Mold flashes are thin layers of cured EMC that form outside the intended substrate area. This anomaly is considered as a mechanical defect, commonly recognized as thin, flaky and excess material due to viscous flow of EMC under pressure. Not only do mold flashes present as cosmetic defects it also constitutes serious risks as it can affect mechanical tolerances, and it requires additional post-mold cleaning process step.

To resolve these concerns, the common practice in the industry is the optimization of the EMCs or the molding parameters. EMC optimization involves reformulation by introducing chemical agents that enhance the performance of the mold compound whereas process optimization dwells on selecting suitable and effective combination of the parameters.

Figure 1: *Post-mold cleaning effect on substrate with mold flash*

Internally, Ampleon alleviates this issue by adding post-mold cleaning via manual scrubbing (see Figure 1). However, this process incurs line interruption, necessitates additional labor and produces handling-related concerns.

1.1 Objectives

This research seeks to mitigate mold flashes via the introduction of mechanical barriers and to pave the way for the possibility of eliminating the additional post-mold cleaning process. By introducing mechanical barrier on the backside of the substrate, the new feature then minimizes the mold flow towards the unintended area down to an acceptable level.

2. 0 REVIEW OF RELATED WORK

Mold flashes happen when EMC unintentionally overflows beyond the designed boundaries during molding transfer. Commonly, this occurs due to mold cavity-to-package substrate incomplete sealing, insufficient clamp force or material rheology variation [1]. These unwanted thin layers of mold compound can form along lead edges, die paddle periphery and most critically for some packages, along the backside edges.

Consequently, these may result in solderability risk as flashes prevent proper wetting of solder during solderability assessment and during reflow. Moreover, it may also lead to leakage currents under high-voltage conditions due to EMC being an inherent insulator. Furthermore, presence of flashes on the unintended portion of the package might affect coplanarity. Thus, this defect necessitates immediate mitigation strategies and resolution.

One of the most common methodologies that address this concern includes process-based approaches (e.g., molding pressure optimization, vacuum-assisted molding), material controls (e.g., low-bleed EMCs), and tool-level improvements (e.g., mold cavity flatness).

In relation to these approaches, Viviani et al. (2023), explored material controls through adjusting filler sphericity supplemented with an additional filler experiment. In that study, it was demonstrated that that reduction of the sphericity of the filler alongside the inclusion of submicron filler eliminated molding compound bleeding and de-flashing process from the assembly flow. This result leads to product quality improvement and manufacturing cost reduction.

Susilo et al. (2024), dwells into optimizing molding parameters. In the study, mold flash was attributed to inadequate pressure and temperature settings. The findings revealed that interactive effects of temperature and injection pressure resulted an enhancement in manufacturing processes.

As for tool-level improvement, Ting et al. (2016), studied mold design enhancement to eliminate mold flash. It was proven that tilting and paddle deformation that is caused by over-clamping enables flashes to occur. The researchers emphasized that the mold tool redesigning in combination with control on critical lead frame dimension resulted in mold flash elimination.

In another study, Gablan et al. (2021), investigated substrate enhancement as a means for mitigating mold flash occurrence by improving the lead frame design, it was demonstrated that modifying lead configuration establishes stability on the lead frame that assisted flash reduction.

In this context, mechanical barriers—physical features integrated on the substrate layout to act as mold flow stoppers—offer a promising direction. Such features (e.g., flash dams, edge seals, or step barriers) can act as physical containment lines that prevent EMC from reaching critical edge-backside areas. Despite their potential, literature on the design, performance, and optimization of mechanical barriers in mitigating backside edge mold flash remains sparse, especially for OMP-type packages.

Therefore, this research aims to evaluate and quantify the effectiveness of mechanical barrier strategies in minimizing mold flash at the substrate backside edges.

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3.0 METHODOLOGY

In this research, the implementation of mechanical steps to minimize entry of mold flashes is the primary focus. A root cause analysis initially done to identify potential contributors to this defect, narrowed it down to (1) Mold tool wear, (2) mold compound variation and (3) substrate misalignment, as factors that exacerbate the opportunity for mold flash formation. Given these findings, the research focused on the integration of a mechanical barrier feature to serve as 'mold flash-proofing' feature. The materials used were manufactured by a single supplier thus plating thickness and surface condition of the substrate are maintained comparable across all lot. As part of the analysis, Substrate A, which represents samples without mechanical barrier (Figure 2a) was compared with Substrate B, units with mechanical barrier (Figure 2b). Figure 2 displays a side-by-side comparison of the substrates being analyzed.

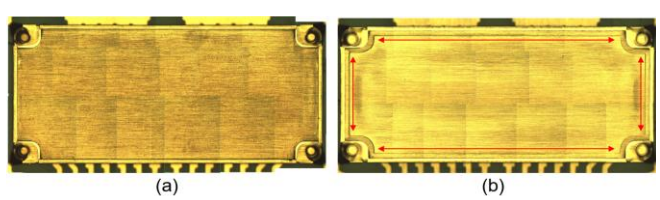


Figure 2: *Side-by-side comparison of Substrate A and Substrate B*

The surface feature and dimension of the mechanical barrier was inspected at material-level while mold flash mitigation was investigated during 0-hr (see flow chart on Figure 3). The height of the mechanical barrier was measured using NEXIV VMZ-R3020 while surface topography was inspected and validated using Bruker Contour GT-K 3D profilometry.

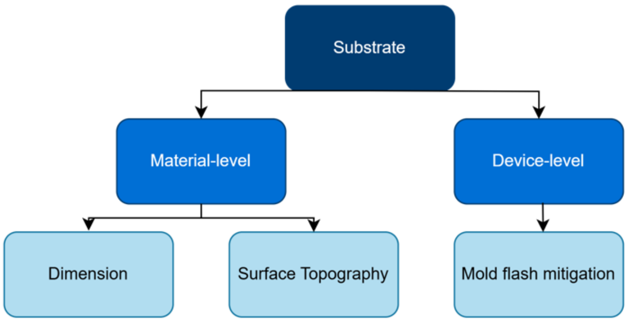


Figure 3: *Flow chart of the study*

Subsequently, both substrates were processed using in-house production set-up and parameters with similar process controls from the front-end up to back-end. To ensure that none to minimal deviation would be encountered, Substrate A and Substrate B were processed in succession at all process steps. For this discussion, due to the risk assessed, this study focuses only on the post-mold outcome.

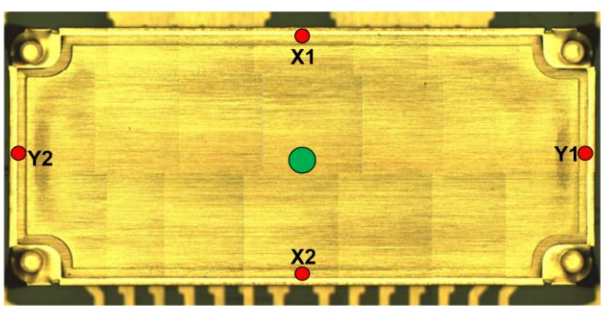


Figure 4: *Measurement points*

Mechanical barrier height measurement was done by taking measurements on the midpoints of each side (left, right, top and bottom sides) from the center of the substrate (refer to image above). However, initial measurements from Nexiv resulted in negative readings despite the visible barrier height and positive values from the Bruker which was attributed to the inherent tilting of the substrate due to the supplier riveting process. As a solution, a reference plane was created on top of the barriers using multiple points. This measurement method offsets the tilting.

4.0 RESULTS AND DISCUSSION

4.1 Material-level: Visual, Dimension and Functional Inspection

As received materials were subjected to visual, dimensional and functional inspection to guarantee that no other variables will affect the mold flash mitigation performance in which both samples passed the established incoming criteria (see Table 1.)

Table 1: *Incoming Quality Control (IQC) inspection result*

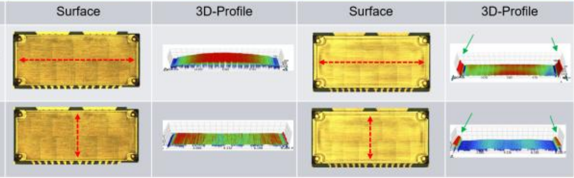
Samples		Visual Inspection	Dimensional Inspection	Functional Inspection
Substrate A (without barrier)	Quantity	125/125	5/5	5/5
	Pass/Fail	Pass	Pass	Pass
Substrate B (with barrier)	Quantity	125/125	5/5	5/5
	Pass/Fail	Pass	Pass	Pass

4.1.1 Material-level: Mechanical Barrier Visual and 3D profilometry comparison

Substrate A and Substrate B backside surface were compared to assess the topography of the mechanical barrier. Analysis was conducted using Bruker 3D profilometry. It can be seen from Figure 2 the substrates visual comparison, wherein the mechanical barrier is visible on Substrate B at 10x magnification and even at naked eye. To evaluate this feature further, the 3D profilometry of the two substrates was compared.

***Table 2**: Surface Topography of Substrate*

	Substrate A		Substrate B	
	Surface	3D-Profile	Surface	3D-Profile
Along the length				
Along the width				



The table above displays the difference in the surface topography of the substrates being analyzed. Substrate A has a flat surface at the backside as no additional feature is visible. On the other hand, for Substrate B, the barrier is recognizable (emphasized by the green arrows) at the edge. The images of the 3D profile highlighted and validated the presence of the mechanical barrier on Substrate B. Due to this apparent feature, it is anticipated to lessen the mold flashes as the height of the mechanical barrier will aid as an obstruction to the mold flow entry. To explore in greater detail, the mechanical barrier height was measured.

4.1.2 Material-level: Mechanical Barrier Dimensional Measurement

Focusing on the dimensional measurement of the mechanical barrier, 31 units were measured via Nexiv on the midpoint of each side. The graph below shows the average and distribution of the readings obtained. Sides along the length (left and right sides) have comparable readings similar with the sides along the width (top and bottom sides). However, comparing the measurements between the sides along the width and along the length, a difference is noticeable. To evaluate the significance of this difference, Analysis of Variance (ANOVA) and Tukey's pairwise comparison was used.

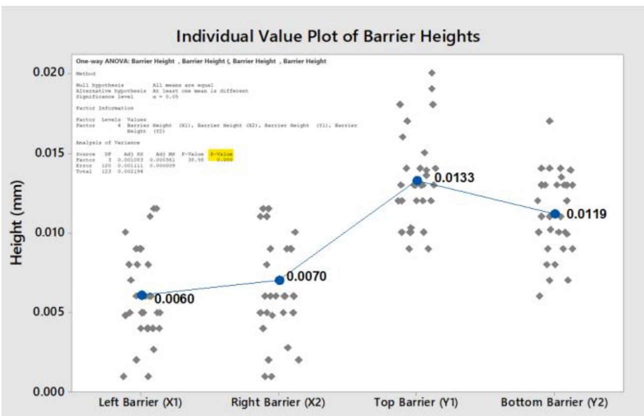


Figure 5: *Individual value plot of barrier heights*

It was verified that there is a significant difference between the groups as verified by ANOVA as the obtained p-value = 0.000. To scrutinize more closely, Tukey's pairwise comparison was conducted to specify which readings differ. The post hoc analysis (see Figure 6) ascertained that only the height of the left and right barriers is comparable (sides along the length) while the rest of pairs signifies difference. Using these samples, the implications of these measurements were assessed during the zero-hour molding performance.

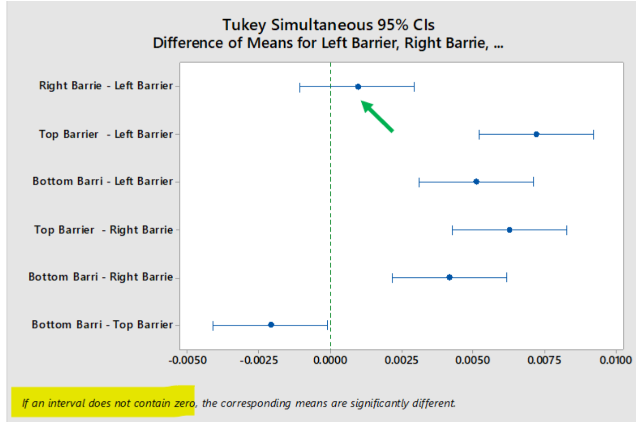


Figure 6: *Tukey pairwise comparison plot*

4.2 Device-level: Mold flash mitigation performance

Images below display the backside comparison of the substrate after molding. It can be observed here that both substrates exhibit mold flashes (pointed by the red arrows). Based on Figure 7a, heavy mold flashes are perceivable at the periphery of all samples revealing that substrate is extremely susceptible to mold flow entry. However, for Substrate B, it is evident from Figure 7b that mold flashes were mitigated, toning the occurrence of heavy flashes from all peripheries down to moderate flashes on the side and minimal flashes on the corner.

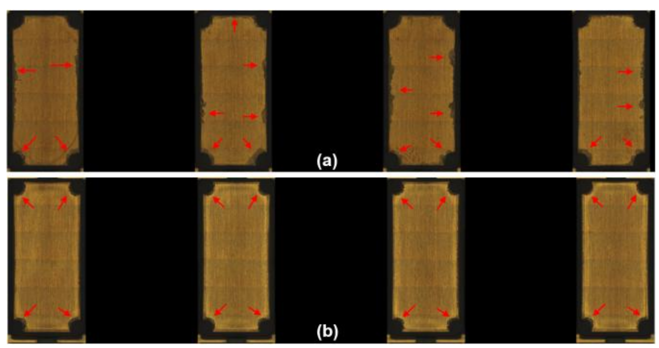


Figure 7: *Post-mold inspection (a) Substrate without mechanical barrier (b) Substrate with mechanical barrier*

During the molding process, another factor that functions as key player is the pressure since it is responsible for driving the EMC into regions of the cavity. Aside from that, pressure also takes place during clamping to facilitate encapsulation. To elucidate further the relationship between pressure and the barrier, classic formula:

$$P = F/A$$

was used where P is the applied pressure, F is the force exerted by the molding equipment, A is the contact area. This formula ascertains that for a constant force (in this case clamping force), the higher contact area the substrate has, the lower pressure is exerted on it which may lead to mold flash formation along the weak boundary areas illustrated by Figure 8b. On the contrary, decreasing the area of contact due to the integrated mechanical barrier increased the local pressure which resulted in improved sealing and reduced flashes as represented by Figure 8d.

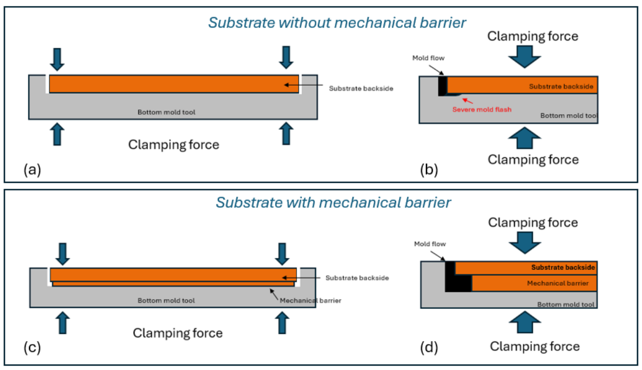


Figure 8: *Schematic diagram of mold flow mechanism on (a) &(b) substrate without mechanical barrier and (c) & (d) substrate with mechanical barrier.*

The mechanical barrier enables the pressure experienced by the substrate to be translated from being distributed on the backside to being localized on the contact area of the integrated barrier. Figure 9 highlighted the significance of mechanical barrier, from the distributed stress shown on Figure 9a (pointed by the black arrows), it was transformed into a localized stress on the area of the integrated mechanical step on Figure 9b (pointed by the red arrows). It can also be seen that the max stress experienced by the sample with barrier is 326 MPa, more than thrice the value of the stress encountered by unit without step 93.7 MPa.

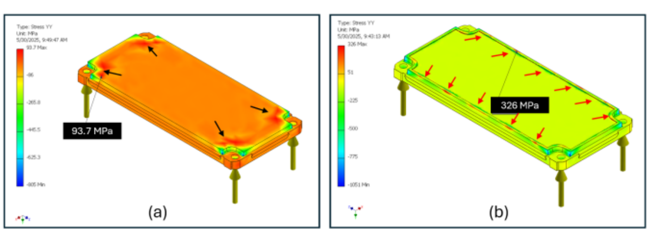


Figure 9: *Stress simulation of (a) Substrate without mechanical barrier and (b) Substrate with mechanical barrier.*

The rechanneling and amplification of the pressure due to the integration of barriers that have smaller contact areas served as physical containment lines that prevented EMC from reaching critical edge-backside areas and guaranteed effective sealing. This outcome ascertained that the sealing mechanism introduced by the mechanical steps resulted in significant mold flash reduction.

Although minimal flashes are still visible, it is clearly indicated by this result that the integration of the mechanical barrier on the substrate is effective in mitigating the mold flow entry as the flashes encountered on the sides and corner become limited. The occurrence of the minimal mold flashes despite the addition of mechanical obstruction could be attributed to the significant difference detected on the barrier height. It seems that the identified disparity could be a point of entry for mold flow.

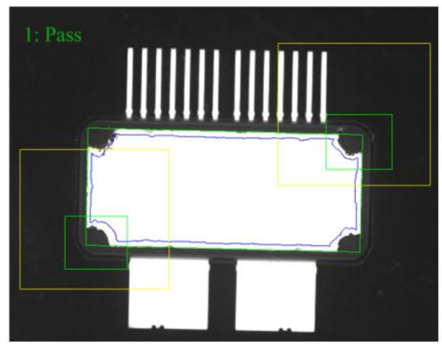


Figure 10: *Sample image of Substrate B under Microvision test*

To quantify this improvement, mold flash Automated Optical Inspection (AOI) was conducted via Microvision Test. Sample image above represents the sample with worst case appearance of mold flash of Substrate B. In this test 97.69% yield was obtained, a significant improvement from 41.30% yield of Substrate A.

5.0 CONCLUSION

It was explored from this research that the integration of mechanical barrier on the substrate effectively mitigated the occurrences of mold flashes. The inherent traces of heavy flashes at all peripheries are significantly reduced by the introduction of anti-mold flash barrier. This improvement in the substrate design toned down heavy flashes on the mold periphery which resulted in a significant yield improvement, increasing from 41.30% to 97.68%. This approach provides practical solution to tone down mold flash occurrence, reducing yield loss and post-mold cleaning process.

6.0 RECOMMENDATIONS

This study focuses on the substrate design enhancement alone, hence, to further improve the mold flash mitigation performance process optimization and/or adjusting mold compound controls could be employed to complement the improvement obtained. Another recommendation is tightening of the barrier dimensions to achieve better mitigation performance. Uniformity on the specification might lead to mold flash elimination as mold flow entry is expected to be completely prevented.

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.
- Marilou Bigcas - Sr. Director, Operations, Ampleon Phils., Inc.
-Gerardo Alvano – Sr. Manager, Design development, Ampleon Phils., Inc.
-Nenita Ignacio – Sr. Manager, Quality & Reliability, Ampleon Phils., Inc.
- Rommel Obed – Sr. Engineer, Quality & Reliability, Ampleon Phils., Inc.

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9.0 ABOUT THE AUTHORS

This section describes the author's educational background and employment history.

Mark Andrew T. Tabucanon is a University of the Philippines – Diliman 2020 alumnus who graduated with a degree of B.S. in Materials Engineering. He has experience in the research field and worked as a Science Research Specialist in academic settings. Currently, he is employed as a Materials Engineer under Quality and Reliability Department at Ampleon Philippines, Inc

Jocy P. Castillo is a Materials Engineering Senior Technician in Ampleon. She started her career in Ampleon Philippines as a FA/ Reliability inspector and then as a Specialist inspector for Incoming Quality Inspector. Her expertise is on Material specifications, quality compliance, product reliability, material-level risk assessment and material characterization.

John Michael V. Tenorio is a Materials Engineering Technician in Ampleon. He started his career in Ampleon as Process Control Operator until becoming a Materials Technician. Throughout his experience in the industry, he gained valuable knowledge on Scanning Acoustic Tomography, X-ray, back-end process and product reliability.