An Alternative Packaging Solution in Achieving Moisture Sensitivity Level One (1) for Small Outline Integrated Circuit (SOIC) Automotive Packages

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Abstract—In response to the need in the semiconductor industry to have a higher moisture sensitivity level (MSL) satisfying the no delamination criteria in all interfaces for automotive devices with a reasonable cost are the main objectives in this study. To attain these tasks, knowledge of the material components and a system in the evaluation process are the key to the success of this program. Different evaluation stages were initially defined and executed depending on bill-of-material (BOM) combination and complexities. Activities will also include process refinement, material selection, leadframe design improvement and surface enhancements. Initially, all existing critical process parameter conditions were identified and optimized to ensure a delamination-free package at time zero or after assembly after which moisture soaking is done at different conditions to identify and verify MSL capability. Once found incapable for no-delamination criteria, the change in mold compound material, leadframe design enhancement, and surface roughening will be introduced. For an SOIC package with the biggest silicon die and paddle size identified as the initial qualification test vehicle using a bare copper with spot silver type of leadframe, it was found out that with the optimized process parameter conditions and with the right mold compound can already achieve MSL 1 and even after 500 temperature cycles without any form of delamination in all regions - no need for further leadframe design enhancements, surface roughening treatments and additional process for surface activation. With this result on this specific package type, additional cost adders were avoided. Likewise, this solution will be extended to other package types with different surface finish for Pre-Plated Frames (PPFs) or Nickel-Palladium-Gold (NiPdAu) to check for process consistency and material compatibility.

Keywords—MSL, leadframe, delamination, PPF, NiPdAu

I. INTRODUCTION

The high demand of automotive products in the semiconductor industry forced the integrated circuit (IC) assembly houses to provide for a more robust packaging solution. The question now lies on how to improve the package reliability and integrity without sacrificing cost. Primary considerations on how to achieve a reliable product involved process improvements and new set of materials that can meet the current automotive industry standards. One of the most common failure mechanisms that are now being addressed are interfacial delamination which are products of weak interfacial adhesions of materials used. Interfacial adhesion should be close to perfection in a way to compensate the coefficient of thermal expansion (CTE) mismatch especially at elevated temperatures. Normally, these weaknesses are being aggravated if process conditions and manufacturing environment are not optimized. The area which these occurs are on the silicon die to the epoxy molding compound and die attach adhesive but however commonly seen between the metal substrate and the epoxy molding compound. The minute interfacial delamination often propagates as temperature increases affecting the bond integrity of the package resulting either to decrease the thermal or electrical performance of the device. And typically, epoxy molding compounds with high adhesion strengths were introduced to address the issue.

This study aims to eliminate delamination occurrence not only after assembly but as well as after moisture soak. Methodology in process and material evaluations were initially defined to reduce evaluation time as well alternative options such as material change or changes to further improve package integrity and reliability. The chosen test vehicle in the course of the study was based on the worst package affected with delamination with the biggest die and leadframe paddle dimension available in the factory.

II. REVIEW OF RELATED WORK

Possible failure mechanisms from plastic encapsulated package failure modes due to delamination are shown in Figure 1 thru Scanning Acoustic Topography (SAT) test. Images illustrates areas affected with delamination: a) the silicon die to mold compound interface, b) At the leadframe paddle to mold compound interface, c) At the die attach – silicon-leadframe interface, d) At the leadfinger tips to mold compound interface, and e) At the bottom of the leadframe paddle to mold compound interface. Figure 2 shows one of the most common failure modes (pop-corning) as a result of delamination, moisture accumulation, and pressure release within a plastic package during the board mounting process [4].
A typical assembly process flow shown in Figure 3 a copper based lead frame: 1) wafer sawing step; 2) adhesive dispensing and placing the silicon die unto to the laminate paddle area; 3) die bond curing; 4) bonding of wires either gold or copper wires; 5) encapsulation step using an epoxy based molding compound; 6) post mold cure; 7) plating the outer leadframe fingers; 8) anneal/bake to ensure no tin whiskers growth; 9) marking using either laser or ink and 10) trim, form, and singulation.

III. MATERIALS & METHODS

A. Materials & Equipment

A copper based with silver on paddle and lead finger tips 14L SOIC with a pad dimension of 94x225 mils and a silicon die size of 84x177 mils was chosen as the qualification test vehicle. Likewise, shown in Table 1 are the material properties of the mold compound materials used. Existing assembly process flow and conditions as shown in Figure 3 were utilized in the course of the study. The assembled units were then soaking at different conditions shown in Table 2 per IPC and JEDEC requirements and classification. A Scanning Acoustic Microscope was also used to identify regions affected with delamination.

B. Methods & Material Selection Process

The decision process flow definition shown in Figure 4, solution classifications will be derived.

(A) Short Term Solution:
Initially, optimum process conditions were established thru the following:
1.0 Die attach curing: must ensure continuous flow of nitrogen gas inside the curing oven
2.0 Wire bonding process: must further ensure minimal bonding time and exposure to higher temperature
3.0 Molding step: best in-mold cure time and clamp pressure
4.0 Post Mold Cure: nominal requirement per technical data sheet will be used
5.0 Plating & De-flash: Optimized plating current conditions

(B) Long Term Solution: BOM Change & Process Improvement:

With the fix in (A) and with the use existing BOM if delamination still present whether after assembly or after moisture soak, option (B) will be executed. The priority of change in the BOM will be the mold compound in which the known best materials will be evaluated. Shown in Table 1 are the typical material characteristics of the known best materials.
that will be used in the selection process. In addition, plasma process will likewise be added as a possible option or solution in the evaluation matrix as shown in Figure 5. Furthermore, units will be subjected up to 500 temperature cycles (-65°C/150°C) and SAT will be performed to check for capability. The best material will be chosen and will be subjected further to a higher MSL & temperature cycles to check its capability.

Figure 5. Mold Compound Selection Process Flow

(C) Long Term Solution: BOM Change + Roughened Frames & Process Improvement:

If still option (B) is not successful in eliminating delamination, surface roughening treatments will be introduced as the ultimate solution. Evaluation flow will proceed as shown in Figure 6 otherwise a complete evaluation re-run will be made.

Figure 6. Roughened Frames Evaluation Process Flow

IV. RESULTS & DISCUSSION

The interface between mold and lead frame is one of the regions that are most susceptible to delamination due to build-up of high stresses and pressure (i.e. due to CTE mismatch and moisture release, respectively). Hence, it is also most susceptible to crack formation during reflow soldering [3]. Optimizing the process conditions defined in the short term fixes helped to minimized if not eliminate the delamination occurrence after assembly and after moisture soak. However due to some uncontrolled production conditions and BOM limitations, it was opted to proceed to the long term fixes. Per development hierarchy shown in Figure 7, considering cost was also considered in addressing the issue.

Since the leadframe surface is more prone to acquire contamination from succeeding process steps such as die-attach and wire bond, any contaminants induced either physically or thermally would reduce the interfacial strength making it easy to delaminate. The next step was to change the BOM, the mold compound in particular. Shown in Tables 3, 4, and 5 are the delamination responses after moisture soak and temperature cycles. Since the current sensitivity level for the chosen or worst test vehicle is at level three (3) only, the selection process was initially started at that level to check for the new BOM compatibility and capability.

Results in Table 3 shows that of the seven (7) mold compounds evaluated, six (6) showed good results after moisture soak, whether with or without plasma. To further mitigate the package robustness, all samples except for Sample C were subjected to 500 temperature cycles and delamination was checked across all regions leaving Samples A, F, and G. Consistently after 1000 cycles, Samples F and G are the best materials though Sample A pass the requirement but with plasma requirement.

Table 3. Delamination Check after MSL 3 and Temperature Cycles

To further check the new BOM capability and consistency for samples A, F and G, all the samples were further subjected to moisture soaking sensitivity levels 2 and 1 conditions as shown in Tables 4 and 5 respectively. Based on the delamination responses after 1000 cycles, the best material was Sample G even without plasma requirement.

Table 4. Delamination Check after MSL 2 and Temperature Cycles

Since item (B) Long Term Solution: BOM Change & Process Improvement already meets the requirement for no delamination criteria in all interface after MSL and TC, it was opted to proceed further in the package qualification activities. While Option (C) Long Term Solution: BOM Change + Roughened Frames & Process Improvement, will serve as back-up just in case issues will arise in the full package qualification as well as confirmation runs for other package types and leadframe surface types.
Furthermore, shown in Table 6 are the delamination results after MSL (in all interfaces) using Sample G. This initially confirms the selected material works with other package types with variable leadframe surface conditions.

### Table 6. Confirmation Runs

<table>
<thead>
<tr>
<th>Package Type</th>
<th>Leadframe Finish</th>
<th>MSL 1 Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSSOP16</td>
<td>NiPdAu</td>
<td>Pass: No Delam</td>
</tr>
<tr>
<td>SOIC8</td>
<td>NiPdAu</td>
<td>Pass: No Delam</td>
</tr>
<tr>
<td>SOIC8</td>
<td>Cu with Spot Ag</td>
<td>Pass: No Delam</td>
</tr>
<tr>
<td>TSSOP16</td>
<td>NiPdAu Rough</td>
<td>Pass: No Delam</td>
</tr>
</tbody>
</table>

### V. CONCLUSION

Interfacial delamination is one of the most challenging defects encountered IC packaging that often results to other package failures. However, such defect can be eliminated with the right assembly process conditions and with the correct bill of material combination. Choosing the best option as illustrated in Figure 7 is likewise very important in considering change with respect to cost effective solution. Having Sample G, being compatible for both CuAg and NiPdAu finishes offers the best solution in improving package reliability and integrity, as well as productivity.

### VI. RECOMMENDATIONS

To further validate performance of the chosen solution in achieving a delamination free package after moisture soak, it is highly recommended to extend the study to other package types with higher CTE mismatch, i.e. packages with exposed pads. The authors also recommend having another set of confirmation runs with respect to mold compound lot to lot delivery and variability and process consistency prior to the large scale validation runs.

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### REFERENCES


