Resin bleed improvement on surface mount semiconductor device

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Abstract. Resin bleed is a transparent layer of epoxy compound which occurs during molding process but is difficult to be detected after the molding process. Resin bleed on the lead on the unit from the focused package, SOD123, can cause solderability failure at end customer. This failed unit from the customer will be considered as a customer complaint. Generally, the semiconductor company has to perform visual inspection after the plating process to detect resin bleed. Mold chase with excess hole, split cavity & stepped design ejector pin hole have been found to be the major root cause of resin bleed in this company. The modifications of the mold chase, changing of split cavity to solid cavity and re-design of the ejector pin proposed were derived after a detailed study & analysis conducted to arrive at these solutions. The solutions proposed have yield good results during the pilot run with zero (0) occurrence of resin bleed for 3 consecutive months.

1. Introduction
A semiconductor company in Malaysia continues to receive customer return for SOD 123 package from various customers and having internal detection with complaints of their undesirable lead colour. Resin bleed is a transparent, brownish layer of mold-epoxy resins which occurs on the surface of the leads as shown in Figure 1, which happened after the encapsulation (molding) process. It is not visible immediately after molding process because resin is a colorless component of the molding compound. It can be only observed after the tin-plating process. The area experiencing the resin bleed will not be plated with tin-plating. The criteria set for resin bleed is that if the bleed is more than 0.1 micron in any direction at any location on the lead and bottom of the lead, the unit is a reject unit. Resin bleed can cause solderability issue on the customer side.

Resin bleed observed in the SOD123 package could cause solderability issue on the PCB board during mounting by the customer. This failed unit if returned to this semiconductor company would be considered as a customer complaint. A significant amount of money and resources needed for the submission of an 8D (Eight Disciplines of Problem Solving) to the customer for the complaint. 8D (Eight Disciplines of Problem Solving) is a meticulous process used to solve complex problems.
Figure 1. Example of resin bleed.

Resin bleed occurs because the resin which is a colorless adhesive material mixed with the silica filler to form the mold compound bleeds out of the cavity during molding to the lead thus coating the lead with a colourless layer.

There are various reasons that can cause resin bleed and does not need to be confined to only the molding process. Tung and Wang [1] clearly stated that the variance formed between the mold plate and the lead frame caused resin bleed on the leads. Kerk, Tey, and Hu [2] also stressed that a lead frame with no full flatness on the surface of the copper lead frame could cause resin bleed. Since the compound flows through the lead, the resin tend to stick on the lead. Tong, Wong and Yu [3] mentioned that in current practice, the setting of molding parameters was done by engineers in a trial-and-error manner could be one of the reasons for resin bleed.

Numerous methods were proposed by researcher to encounter resin bleed. Kerk et al. [2] stated that resin bleed could be solved by using chemically etched copper lead frames. Resin bleed could also be solved by electrical deflash and high pressure water jet. This is a process that softens the adhesion resulting the removal of organic compound on the surface of the frame as proposed by Marvin and Gavino [4]. Paquet [5] stated that the control of the injection molding parameters, such as transfer speeds, mold temperature, clamping force and transfer pressure, could generally help to eliminate the emergence of resin bleed and void. To eliminate resin bleed, Chiang and Su [6] applied Fuzzy quality loss function (FQLF) to the qualitative responses, since the molding defects cannot be simply represented by the relationship between molding conditions and mathematical models. Another comprehensive and proven method to stop resin bleed is to modify the lead frame to have a control step down in the perimeter of the cavity as explained by Colin, Boon, and Shugumar [7]. This step-down would act as a drain to trap all the resin which tends to bleed out. Carrie and Lim [8] proposed that placing an adhesive tape on the exposed pads side to prevent resin bleed during encapsulation which would be able to prevent mold compound resin bleeding to the exposed pads.

The current control for resin bleed in this company is to perform weekly imprint check on the SOD123 molds to check for mold balancing. If there was a weak imprint trace as in Figure 2, it showed the mold was imbalanced. The mold would then be repaired to improve the mold balance which would be verified through visual inspection on an imprint paper as in Figure 3.
Since the resin bleed was due to weak clamping at the lead area, it was possible to increase mold clamping pressure which increased the lead impression, eventually reducing the bleed. But this is not a recommended solution as it could lead to other issues such as lead flash and smash lead. Approach of increasing the setting of the high pressure water jet (HPWJ) to remove the resin bleed was also considered but was not a viable choice as it would affect the package reliability.

2. Methodology

2.1 Measurement system analysis (MSA) study- Attribute gage repeatability & reproducibility (GR & R)

An attribute Gage Repeatability & Reproducibility (GR&R) study was done to measure the efficiency of the pre-gate operators to detect resin bleed reject and also to avoid over-rejection/escapee during pre-gate process. 15 serialized samples consisted of reject and accept units were given to the all three shift pre-gate operators. There were two possibilities; either the operator are over-rejecting or under rejecting. To solve this problem, all the 6 operators were given training and the GR&R study is done again. When the study was conducted after this training, the result of the study showed a positive improvement.

2.2 Root cause identification

The current mold used in the production line consisted of two platforms, converted from 2 rows to 3 rows platform and dedicated 3 rows platform. Figure 6 depicts the Multi-Vari analysis result plotted by the mold machine and platform using trim & form pre-gate data from January 2013 till December 2014. It could be seen from figure 6 that the converted 3 row molds were having a higher contribution of resin bleed compared to the original 3 row platform. The first phase of further analysis would be on the high occurrence of resin bleed in converted 3 row platform and the second phase would be on occurrence of resin bleed in dedicated 3 row platform.
2.2.1 **Comparison between converted and dedicated 3 rows platform.** Initially SOD123 lead frame has 2-row. In year 2002, there was an increase in lead frame density for SOD123 from 96 units to 144 units whereby the number of rows in a lead frame was increased from 2 rows to 3 rows. To cater to this change, the mold parts were modified. The mold cavities were new but the chases as shown in Figure 7 were re-worked to cater to the new mold cavities. The reworked chase has many unwanted holes which caused excess compound to sip under the chase when there was a compound leak causing the mold surface to be imbalanced.

2.2.2 **Analysis converted 3 row platforms.** Based on the cause & effect diagram in Figure 8, there were four main possible categories to cause resin bleed which were material, machine, human handling and method.
From the cause & effect diagram, the cause & effect matrix was done as in Table 1 and it was found out that the most probable factors were as below;

- Imbalance mold clamping
- Abnormal/Damage parts

**Table 1. Cause & Effect Matrix.**

| No. | Input / Process Indicators | Y1 | Y2 |
|-----|---------------------------|----|----|
| 1   | Abnormal/damaged incoming lead | 0  | 1  |
| 2   | Placing double strip       | 0  | 1  |
| 3   | Mold cleanliness not maintained | 0  | 1  |
| 4   | Inefficient air gun brushing | 0  | 1  |
| 5   | Imbalance mold clamping    | 3  | 3  |
| 6   | Incorrect Mold parameter setting | 0  | 1  |
| 7   | Abnormal/Damaged parts      | 3  | 9  |
| 8   | Insufficient Mold clamping tonnage | 0  | 1  |
| 9   | Lead slot depth             | 0  | 1  |

**Output indicators >>>>>>**

| Importance >>>>>> | Y1 | Y2 |
|-------------------|----|----|
| 10                |    |    |

**Resin Bleed Occurred to Particular Mold (21 - 24)**

**Resin Bleed Occurred to Random Mold**

**Correlation of Input to Output ------**

**Total**

**Rank**

2.2.3 **Analysis on dedicated 3 row platform.** Mold #19 & #20 were basically identical to each other except that mold #19 was newer than mold #20. It was observed that mold #20 was using split cavity as shown in Table 2.
Table 2. Comparison between Mold 19 & Mold 20.

|               | Mold #19                     | Mold #20                      |
|---------------|------------------------------|------------------------------|
| Chase         | Originally 3 row            | Originally 3 row             |
| Cavity        | Solid Cavity                | Rework split cavity & solid cavity |

2.2.4 5-Why Analysis & Solution Selection. 5-Why Analysis as in Figure 9 and Figure 10 was used on the most probable factors to further investigate the root cause derived from the cause and effect matrix which were imbalanced mold clamping and abnormal/damage parts. The possible counter measures were evaluated and the best solution was selected.

**Figure 9. 5-Why Analysis on imbalance mold clamping.**

2.2.5 Rework split cavity. The lead slot depth of the cavity by design must be within the range of 0.094 mm to 0.097 mm. Lead slot was the position where the lead rest in the mold cavity. The lead needed to
be clamped to ensure the compound did not not flow out to the lead during the molding process. Analysis was done after measuring the lead slot depth at 30 positions in one set of split rework cavity. The Chi Square value and t-value as in Figure 11 shows there were significant differences between the actual reading in the split rework cavity & the specification.

The lead slot depth was critical as an excessive clamp force on the lead could cause smash lead and low clamp force on the lead could cause resin bleed. Based on the specification, the maximum allowable lead slot depth was 0.097 mm which gave a minimum height difference between lead thickness and the lead slot depth of 0.012 mm. Based on the measurements taken on the split rework cavity, the lead slot depth was above 0.10 mm. This gave the height difference between lead thickness and the lead slot depth less than 0.012 mm. This would cause the resin from the compound to bleed out onto the lead.

![Figure 11. Analysis result on the split rework cavity lead slot depth.](image1)

![Figure 12. Illustration of Lead slot and lead.](image2)

3. Results and discussion

3.1 Generating & evaluating solution

| Possible solution | Evaluation Result | Conclusion |
|-------------------|-------------------|------------|
| 1. Fill up extra hole in the chase with teflon | Filling up the extra hole using teflon cause the chase to be imbalance when placed onto the mold base | Not Applicable |
| 2. Use new chase with no extra e-pin holes | There is no gap for the compound to leak under the chase | Applicable |
| 3. Train line tech for proper installation of chase | Training done but still the installation is human dependent. Still has OFE | Not Applicable |
| 4. Change the ejector pin hole design in cavity bar | Installation of the chase is more easier and less hassle since the hole is tapered | Applicable |
| 5. Change all cavity to solid block cavity | Better imprint result & easier to control mold impression | Applicable |
Some solutions in Table 3 were deemed as “Not Applicable” as they were not systemic solutions but only temporary solutions which can lead to the occurrence of resin bleed. The new chase eliminated the teflon used as in rework chase to close the excess holes which contributed to mold imbalance. The new chase as in Figure 13 with no extra holes as in the new design ensured no mold compound would leaked onto the mold base. This would ensure the mold base would always be flat.

**Figure 13.** Comparison of old and new mold chase design.

The split cavity as in Figure 14 allowed the compound to leak and also possessed potential misalignment which could cause the lead frame to be misaligned. Once the lead frame was misaligned, resin bleed could occur.

**Figure 14.** Comparison of split cavity and solid cavity.

The function of ejector pin was to eject the lead frame from the mold surface once the molding process. The current design of the ejector pin holes as in Figure 15 which was a stepped design caused many ejector pin breakages. This pin then would fall back on the mold base causing the mold to be imbalanced.

**Figure 15.** Comparison of stepped design ejector pin hole and tapered ejector pin hole.

### 3.2 Pilot run & solution implementation

All the three selected solutions were put for trial run at Mold #21. Mold #21 was selected because it was showing high contribution to the occurrence of resin bleed cases cumulatively from January 2013 to December 2014. The pilot run was conducted for 3 months and the effectiveness of these solutions would then be measured with the detection at the in-process inspection.

Pilot run result – After 3 months of pilot run, it was found that by implementing the selected solutions, the reduction of the resin bleed cases detected during inspection could be observed as illustrated in Figure 16. Hence, it could be concluded that the three solutions were able to reduce the resin bleed occurrence in all the molds.
4. Conclusion

Three root causes have been identified and improvement actions were implemented to address these root causes of resin bleed in SOD123. The major root causes of resin bleed in SOD123 package during molding were usage of rework chase, usage of abnormal/damage parts (split cavity) and ejector pin hole design in the cavity block which lead to breakage of ejector pins. All of these root causes pointed to the mold compound leaking to the mold base causing the mold to be imbalanced. When the mold became imbalanced, mold compound tended to leak onto the lead of the package causing resin bleed. To tackle the identified root cause, three solutions were identified and evaluated. The solutions were new mold chase with no extra holes, replacing all split cavities with 1-piece solid cavity and re-designing the ejector pin hole from step design to tapered design. After the implementation of these refurbishments with the selected solutions, the occurrence of resin bleed was reduced significantly. The pilot run done on mold #21 which was having the highest occurrences showed zero (0) occurrence of resin bleed for three consecutive months (July 2015 to September 2015) from the implementation of the selected solutions hence proving the effectiveness of these methods. With the pilot run results showing that internal occurrence was good for three consecutive months, it showed that the issue had been resolved and customer would be receiving no reject units.

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