Staging Time Evaluation of Transfer Molding to PMC Process Towards Delamination on IC Package

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Abstract. Moisture-induced delamination is one of the reliability concerns in electronic packaging. This work evaluates moisture absorption changes by the staging time approach during the transfer molding to the post molding curing (PMC) process and the impact of moisture changes on the delamination of the integrated circuit (IC) packages. These experimental results can be used as a recommendation to determine the limit of staging time in line production properly and how this method can prevent interfacial delamination on packages during the reflow process. The package reliability were observed by perform SAM visual inspection.

Keywords: *Staging Time, Moisture, Delamination, Integrated Circuit (IC).*

1 Introduction

Moisture-induced delamination is one of the failure modes of the reliability performance in electronic packages. There were some studies on moisture absorption influenced delamination. It is known that if plastic encapsulated IC package are exposed to humid ambient conditions during manufacturing, transfer process or and storage before the surface mount process, then the molding compound (MC) would absorb moisture due to it is hygroscopic material. The absorbed moisture turn into vapor steam upon heating at a temperature setup and generate trapped air with pressure inside the package. The high vapour can trigger defect delamination or cracking occurred [1][2].

In order to minimize the moisture in a mold compound, the packages are needed to carry out an advanced process after molding, namely the PMC (post molding curing) process. This process is intended to reduce the moisture from the package. Tina li, etc have studied PMC effect on package delamination with different epoxy mold compound (EMC) types. It is seen that the applied PMC process achieved a reduction in package delamination with optimum interface adhesion of materials[3]. Ming-Yi Tsai, etc found residue stresses and deformations caused by

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chemical shrinkage can be relaxed in the PMC process through their experiment conducted incorporated EMC viscoelastic effect and stress release during package fabrication[4].

The reliability performances of IC should be tested by considering the moisture sensitivity level (MSL) as a user of semiconductor components expects from the supplier. MSL standard describes the humidity sensitivity to the environment and the procedure standard to avoid potential damage related to moisture during the reflow process[5]. MSL is classified according to IPC/JEDEC industry standard procedure J-STD-033, which addressed the problem of water absorption from non-hermetic packages. MSL defined water absorption into 6 different levels toward standardized test criteria. MSL 1 is the least sensitive to moisture and MSL 6 is the most sensitive [6].

An evaluation of reliability performance can be proposed regarding the moisture absorption of the package during exposure to the environment through present the staging time approach and applying preconditioned MSL 3 according to the JEDEC standard[6]. The staging time is defined as the hold time of transferring the package from the molding process to the PMC Process. This paper focuses to evaluate appropriate the staging time from transfer molding to the PMC process and investigating the impact of dynamic contain moisture absorption on interfacial delamination package. The delamination performances were collected by SAM after the reflow process. The gained insight will be used to define how to perform MSL 3 zero delamination as a target to achieve reliability package and acceptable requirement standard.

2 Materials and Methods

The materials selected for the evaluation are the Dual Small Outline (DSO) package of Integrated Circuits (IC). The parameters process for the package type is given in Table 1. By changing the staging time with set-up time from 0 hour (without staging or T0), 8 hours & 24 hours (T1), 48 hours (T2), 72 hours (T3), 96 hours (T4), 120 hours (T5), 144 hours (T6), and 168 hours (T7). Experiment conditions are shown in Table 2. The test has been performed using eight samples of DSO package legs. Each leg consisting of 20 IC units was taken out to determine the percentage of moisture absorption rate and delamination effect.

Table 1. Parameter Process of DSO package on Molding and PMC Process.

Process	Temperature	Curing Time
Molding	175^0C	80 sec
PMC	175^0C	7 hours

This work was conducted by following a systematic process flow (Figure 1). The use of the staging time approach in the DSO package starts after the molding process. Every strip was transferred to the trim form and singulation process (TF 1 & TF2) to get the single IC unit of the package. Weighing is done for all units. Each experiment of the samples was carried out 20 units per strip. The sample T0 was immediately continued to the PMC process without staging. Meanwhile, the other samples (T1 to T7) were staging. The IC unit of the samples (T0-T7) was weighed after the staging time (before) and after the PMC process (a check mark (√) is given if unit IC from each process output is weighed, see Table 2). Further, the sample will be reflowed about 3 times and the final step is using SAM for characterizing IC delamination.

Table 2. Design of Experiment

No. of Leg	Sample label	Staging Time	Weighing	
			Before PMC	After PMC
1	T0	No staging	√	√
2	T1	8 hours & 24 hours	√	√
3	T2	48 hours	√	√
4	T3	72 hours	√	√
5	T4	98 hours	√	√
6	T5	120 hours	√	√
7	T6	144 hours	√	√
8	T7	168 hours	√	√

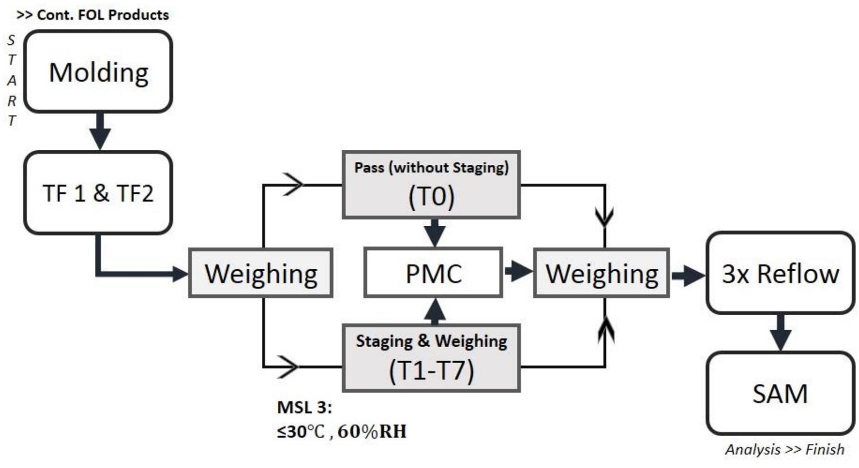


Fig 1. Experimental process flow.

Plastic encapsulated electronic packages are susceptible to delamination during the reflow process after absorbing moisture. In the reflow oven, cracks may be initiated due to the combined effect of hygro-mechanical stress, thermo-mechanical stress, and the adhesion strength degradation at the material interfaces[7]. At high temperature, water vapor will quickly diffuse into the existing cracks vaporize. The build-up of high vapor pressure within the crack may cause violent crack propagation. This work used 3 times reflow so that the moisture trapped in the package will vaporize when heat is applied. The process is proposed to reduce the surface tension at compound to accomplish the strength bonding in intermetallic material of packages as requirement of acceptable standard.

The electronics packages can be sensitive to moisture when exposing to environment. In order to prevent delamination occurring during reflow process, the moisture content of the package must be well controlled. The moisture sensitivity is classified according to the level defined per Ref.[6] MSL classification is introduced to identify electronics packages performance from MSL 1 to MSL 6 at a reflow temperature of 260°C. During the component reliability qualification, the sample shall be preconditioned according to the classified level. In this work, the moisture precondition is set at a room temperature of 25℃ and relative humidity (RH) of 60%.

Moisture absorption and desorption properties of semiconductor packaging materials were determined by measuring the increase or decrease in weight on the IC using a scale as a time function [8]. The moisture uptake rate percentage was calculated for every unit single of ICs with different time staging using equation 1, where M1 (gr) is the initial weight of the unit sample IC and M2 is the final weight of the sample (gr) after post-mold cure for a time period *t*.

$$\text{Absortion Rate (wt\%)} = \left(\frac{(\text{M2}-\text{M1})}{\text{M1}}\right) \text{x } 100\ \% \qquad (1)$$

After finishing the moisture absorption, delamination tests were performed using scanning acoustic microscopy (SAM). SAM provides non-destructive test imaging of delamination in the die, chip, and package material[9]. The type of analysis mode was used S-Scans. This mode actually includes C-scan and transmission scanning. The advantage of the mode is able to determine the defect of the specimen sample which has two sides (top and bottom) in a brief time[10]. There are two visual images shown on a computer at the same time. The results were shown in Figure 3. It was found that all the samples were not delamination due to attached moisture absorption change.

3 Experimental Results

3.1 Water Absorption Rate

All the samples are built according to the DoE matrix with different time staging conditions before the post-mold cure process in integrated packaging and applied MSL3 conditions. The moisture absorption rate of units is examined using equation (1) and the delamination is verified by SAM characterization.

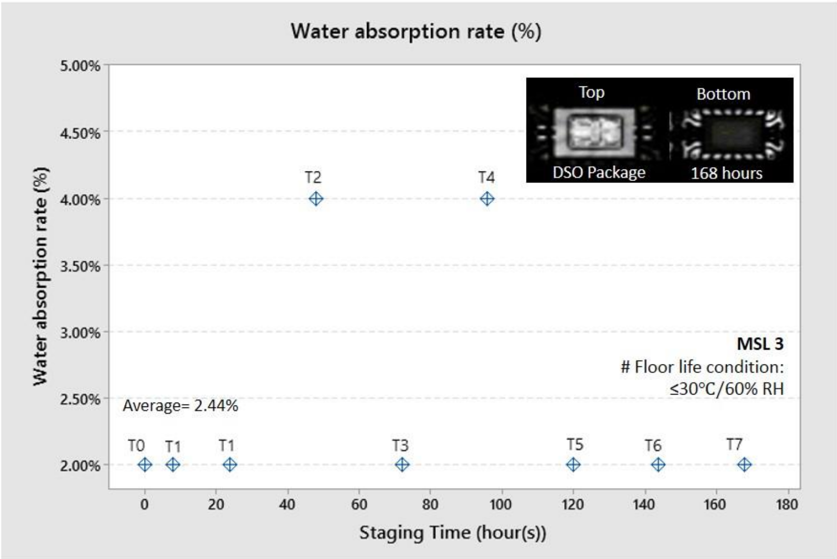


Fig 2. Graph of water absorption rate influenced staging time for the samples (T0 to T7).

Based on figure 2, The moisture uptake is still controlled under 5%. These results were obtained from the data distribution measurement of reconditioned weight of samples after staging at the range 0,57gr up to 0,59 gr. The weight has increased very small when compared with the initial weight of the IC unit i.e 0,57 gr. These results can be interpreted as the package not being too sensitive to moisture when exposed to the environment since the preconditioning humidity is maintained relatively in the line production. Further, the calculation of the average moisture absorption rate on unit IC from all samples achieved 2,44%. Increasing the staging time up to 168 hours for MSL 3 condition (≤30℃/60% RH) showed there is no significant change in humidity.

3.2 SAM (Scanning Acoustic Microscopic) Test Results

The impact of moisture changes to the delamination IC packages due to staging time treatment were observed using SAM Machine. SAM Results were collected from all samples. The samples without staging and staging before the PMC process were inspected delamination on both sides i.e the top and bottom sides of unit IC. Figure 3 show the visual inspection of SAM on sample T0 (without staging), T1 with staging time 24 hours, and sample T7 with staging time 168 hours (MSL 3). The results shows that samples T0, T1, and T7 were not found a delamination effect on both sides i.e the top and bottom sides, respectively. Similar results consistent obtained from others samples that there is no delamination after investigation done, so all samples having zero delamination by confirming visual reference acceptable and defect criteria (Figure 4). Further, all samples can achieve the acceptable standard for IC packaging and pass quality control inspection. It is an expected result.

Based on the results, we can assume that the mold compound used on IC package compatible with MSL 3 which durability duration of 168 hours (7 days). Furthermore, these results can be recommended to set up hold time limit for the package production using the appropriate parameter process standard. A packaging solution to enable the MSL3 zero delamination is an achievable target with further optimization for DSO package.

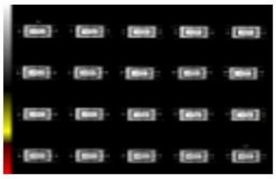
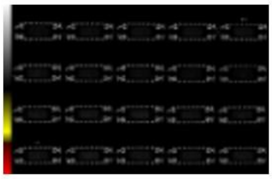
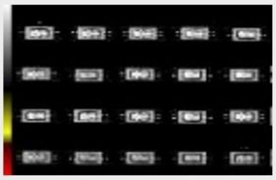
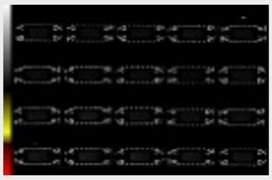
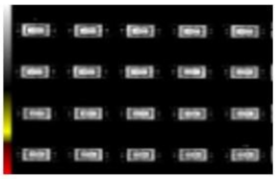
Staging Time Condition	Sample Leg. No	SAM Visual Inspection		Results
		Top Side	Bottom Side	
Without Staging	T0			No Delam
24 hours	T1			No Delam
168 hours	T7			No Delam

Fig. 3. Delamination by SAM Visual inspection on sample T0 (without staging), T1 with staging time 24 hours, and sample T7 with staging time 168 hours (MSL 3).

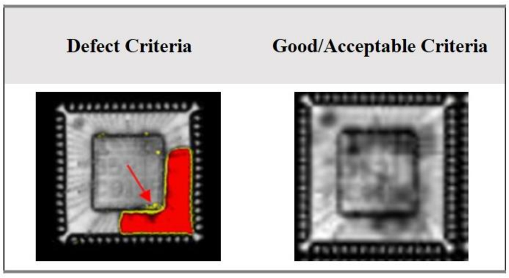


Fig. 4. Visual SAM reference of Acceptable (Right Side) and defect criteria (Left Side) on IC package delamination.

4 Conclusion

This research evaluated staging time before the post-mold cure (PMC) process to investigate delamination issues and optimize the manufacturing process in integrated packaging. In the investigation, the changing moisture in-unit IC with staging time before the PMC process varied from 0 hours, 8 hours, 24 hours to 168 hours to analyze potency staging periods that can be applied to the future production process. The results shows that all the samples were not found a delamination effect on both sides i.e the top and bottom sides of unit IC respectively. Based on the investigation result, we concluded that staging time (up to 168 hours) do not contribute to the delamination and the mold compound used on IC package compatible with MSL 3 which durability duration of 168 hours (7 days). Furthermore, these results can be recommended to set up hold time limit for the package production using the appropriate parameter standard and investigation will be continued with consider more optimize parameter process.

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