Guidelines for Handling and Processing Moisture Sensitive Surface Mount Devices (SMDs)

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Introduction

Certain plastic encapsulated surface mount devices (SMDs) if not handled properly can incur damage during the solder reflow attachment process to printed circuit boards (PCBs). The damage occurs as a result of internal package cracking (commonly referred to as popcorn cracking) and / or delamination between internal package interfaces (i.e., die surface and mold compound). Such internal damage can lead to a number of possible failure modes including broken bond wires and lifted ball bonds. If they reach the exterior of the package they may provide an entry pathway for external contaminants. Furthermore, separations in the die attach region can lead to increased electrical and thermal resistances, which may affect device performance in certain package styles where such a conduction path is required.

The root cause of this type of failure mechanism is the rapid heating of the moisture absorbed within the plastic encapsulant. All plastic packages absorb moisture. During typical solder reflow operations when SMDs are mounted onto a PCB, the entire PCB and device population are exposed to a rapid change in ambient temperature. Any absorbed moisture is quickly turned into superheated steam. This sudden change in vapor pressure can cause the package to swell. If the pressure exerted exceeds the flexural strength of the plastic mold compound, then it is possible to crack the package (see Figure 1). Even if the package does not crack, interfacial delamination can occur.

A number of factors can influence the moisture sensitivity of a package. These include both the internal dimensions and design of the lead frame, the external dimension of the package and the physical properties of the die attach material and mold compound. Also, the die dimensions and even the type of passivation can affect moisture sensitivity. The last two factors which can influence the moisture sensitivity of a SMD are the amount of absorbed moisture and the solder reflow temperature profile. For any given moisture sensitive SMD, once assembled, it is only the latter two factors that a PCB manufacturer has control over.

The amount of moisture absorbed within a plastic package is dependent on four items:

- Physical properties of the mold compound
- Temperature
- Relative humidity of the ambient atmosphere and,
- Time duration at those conditions

The diffusion rate of moisture into the mold compound is temperature dependent. The higher the temperature, the faster the surrounding moisture will penetrate the mold compound. The absorption process will continue until the internal moisture concentration reaches an equilibrium with the ambient relative humidity. Thus the higher the relative humidity, the greater the amount of absorbed moisture within the plastic package.

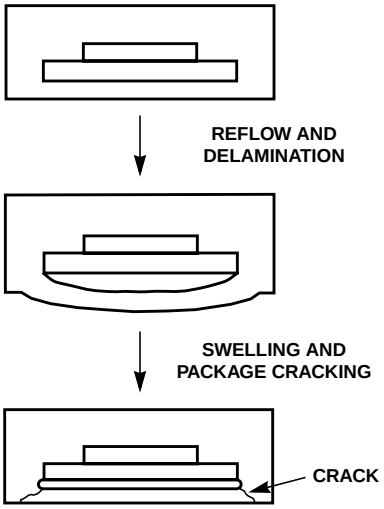

FIGURE 1. CROSS SECTIONAL VIEW OF A MOISTURE SENSITIVE PLASTIC PACKAGE UNDERGOING SOLDER REFLOW. ABSORBED MOISTURE TURNS TO VAPOR, WHICH CAUSES THE PACKAGE TO SWELL.

As mentioned earlier, the profile of the solder reflow process, which includes preheat, ramp up and maximum temperature exposure, also affect the moisture sensitivity of an SMD (see Tech Brief TB334, Guidelines for Soldering Surface Mount Components to PC Boards). In general, the slower the ramp rate and the lower the maximum temperature, the less the probability of potential damage due to moisture sensitivity.

Moisture Sensitivity Classification

In order to establish common criteria for the classification of moisture sensitive SMD packages several industry specification were drafted. The more widely accepted includes JEDEC STD22B, Test Method A112-A and IPC-SM-786A. These have recently been combined into IPC/JEDEC J-STD-020A (Moisture/Reflow Sensitivity Classification for Plastic Integrated Circuit Surface Mount Devices). These specifications outline the test methods to classify the moisture sensitivity of a given SMD to one of eight different levels (see Table 1).

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TABLE 1. MOISTURE SENSITIVITY LEVELS

LEVEL	FLOOR LIFE	
	CONDITIONS	**TIME** (NOTE 1)
1	≤ 30°C / 85% RH	Unlimited (Note 2)
2	≤ 30°C / 60% RH	1 Year
2A	≤ 30°C / 60% RH	4 Weeks
3	≤ 30°C / 60% RH	168 Hours
4	≤ 30°C / 60% RH	72 Hours
5	≤ 30°C / 60% RH	48 Hours
5A	≤ 30°C / 60% RH	24 Hours
6	≤ 30°C / 60% RH	6 Hours

NOTES:

1. Time after removing from dry pack in a ≤ 30°C / 60% RH ambient.
2. Dry pack not required. Maximum conditions 30°C / 85% RH.

The classification test procedure involves a specified soak duration at the stated floor life conditions for levels 3 through 6. Accelerated conditions are used for level 1 and 2. Following the humidity soak, the packages are subjected to 3 reflow cycles with either vapor phase or IR reflow. The specified maximum reflow temperatures are 219°C/225°C or 235°C/240°C depending on package dimensions (refer to J-STD-020A). The product is then subjected to electrical test, visual inspection, cross-sectioning and/or inspection with acoustical microscopy. The package is assigned to the lowest level of moisture sensitivity for which it passes.

Dry Pack

If a particular package style is determined to be moisture sensitive (levels 2 through 6), then the product must be shipped in dry pack. The dry pack bag is a tough, moisture resistant bag. The moisture sensitive product is typically baked for 24 hours at 125°C. Following the bake the product is placed inside a dry pack bag along with predetermined amount of desiccant and a humidity sensitive indicator card. The bag is then sealed. A moisture sensitivity warning label is then affixed to the bag. The label will indicate the floor life after the bag is opened as well as the date the dry bag was sealed. The label will also contain information on storage and re-baking of product.

PCB Assembly

Upon opening a dry pack bag with product, the user needs to check 2 items:

- the seal date on the label, and
- the moisture indicator from within the bag.

If the bag seal date is over 1 year and / or the humidity indicator card shows >20% RH, the product needs to be re-baked prior to reflow. If both the seal date and humidity indicator card are within the requirements, then the product may be used. The solder reflow must be accomplished within the specified floor life shown on the warning label. Failure to do so may result in damage to the product.

Unused product can be stored in a cabinet with a controlled ambient ≤ 20% RH when not in use. When product is returned to production any previous floor exposure shall be deducted from the floor life indicated on the warning label. When a variety of moisture sensitive SMDs are being used, it is extremely important to maintain the sensitivity level and total floor life exposure of each device. The floor life shown on the label is for a maximum factory ambient of 30°C / 60% RH. Derating calculations have been published for use of moisture sensitive SMDs in other temperature / humidity factory conditions [1].

As mentioned before, the ramp rates and maximum temperatures have a direct effect on moisture sensitivity. Moisture sensitivity classification is performed at a maximum temperature of either 219°C/225°C or 235°C/240°C depending on the package dimensions. Higher reflow temperatures may increase the moisture sensitivity of a particular device type because of the associated increase in the vapor pressure of the steam. Other precautions should be observed in instances where reflow is being performed with radiant heating, such as with IR reflow. Heating is not uniform across the PCB. Outer edges of the board tend to get hotter. Also smaller packages with less thermal mass can achieve higher temperatures than larger packages in a mixed PCB design. Profiling of IR reflow systems should be performed to account for these differences.

Several manufacturers employ wave solder for soldering SMDs to PCBs. Typically such soldering is performed at 260°C. This method and temperature range is not recognized by the IPC/JEDEC J-STD-020A and as such SMD packages have not been characterized for moisture sensitivity under these conditions. **If a user is employing this method, they should check with Intersil prior to use.**

PCB Rework

If a rework of a PCB with moisture sensitive SMDs is required, special precautions must be observed. Should the rework require complete exposure of the PCB to reflow conditions, then the manufacturer needs to take into account the shortest floor life of any moisture sensitive SMD on the board. If the floor life has been surpassed, then the entire board should be re-baked.

Localized board repair with a soldering iron or hot bar should not damage neighboring packages. Care should be exercised not to overheat individual leads of the replacement device. If a hot air gun is used for making board repairs, care should be taken to shield any surrounding moisture sensitive packages. If a moisture sensitive SMD is to be replaced, the new device should be within its floor life. Any special requirements, which might be on the product's data sheet, should be followed.

Re-Baking of Moisture Sensitive Product

Moisture sensitive product which has been exposed to the factory ambient past its intended floor life or when the dry pack bag has been opened and the humidity indicator card shows >20% RH needs to be baked dry again before reflowing. The baking process for dry packing is 24 hours at 125^{O}C. Shipping trays can typically withstand this temperature (check with product supplier to be sure). However, shipping tubes and tape and reel cannot. Two alternatives exist:

1. For product in plastic tubes the product can be transferred to metal tubes or placed on metal trays for the normal 125^{O}C bake out procedure. ESD precautions need to be observed.
2. Tubes and tape and reel can also be baked at 40^{O}C +5^{O}C/-0^{O}C at <5% RH for 192 hours or longer.

Following the bake out procedure the product needs to be processed through reflow within its assigned floor life or it can be returned to a storage cabinet with < 20% RH for use at a later time. In the case of extremely moisture sensitive components (level 6) it is advisable to process through reflow immediately after the bake.

Distributors

Dry packed product should be turned on a First In/First Out (FIFO) basis to insure dry pack does not go beyond its one-year expiration date. Preferably factory dry pack should not be opened. If, however, an order requires opening a dry pack bag for part of its content, the bag should be resealed immediately and the removed contents transferred to a new bag. The new dry pack bag shall meet Class I barrier requirements per Federal Test Method Standard 101, Method 3030. Resealing of the new dry pack should occur within 30 minutes maximum and should follow the requirements of EIA-583 (Packaging Material Standards for Moisture Sensitive Items) and / or IPC/JEDEC J-STD-033 (Standard for Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices). A duplicate of the same moisture sensitive warning label as on the original dry pack bag shall be affixed to the new bag. If the product is exposed for greater than 30 minutes, re-baking should be performed.

References

[1] *"Diffusion Model to Derate Moisture Sensitive Surface Mount ICs for Factory Use Conditions"*, R. L. Shook and T.R. Conrad, Proc. 45th Electronic Components and Technology Conference, pp. 440-449, 1995

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