

Plastic Package Moisture-Induced Cracking

Introduction

With the older "through-hole" technology packages such as the Dual In-line Package (DIP), soldering to printed circuit boards was accomplished using a wave solder. The DIP leads went through holes in the printed circuit board, where they were exposed to molten solder during the mounting process. The DIP's body was never subjected directly to the solder melt, because it was protected from the heat of the molten solder by the printed circuit board.

However, with the advent of "surface mount" technology (SMT), i.e., PLCC, PQFP, and SOP, the problem of plastic package moisture-induced cracking arises. The higher lead count surface mount packages have reduced lead pitch compared to through-hole packages. As a result, SMT packages have to be mounted directly to the board surface rather than through it. The advantage of surface mounting allows both package body size and thickness to decrease, while lead count increases. Essentially, a higher density of integrated circuits can be mounted on a printed circuit board using surface mount packages instead of through-hole packages. Soldering surface mount packages directly to printed circuit boards has to be performed by directly heating the entire surface mount package and the PC board together. Direct heating of the surface mount package, combined with its ability to absorb moisture vapor, increases the likelihood of moisture-induced cracking during reflow conditions.

Purpose

Due to the moisture-induced cracking susceptibility of surface mount packages, the events that lead to cracking need to be explored, along with some typical methods for preventing these assembly defects. The intent is to maintain reliable, crack-free surface mount plastic packages under solder reflow conditions.

This section discusses the areas of moisture absorption, reflow conditions, plastic package cracking, dry packing procedures, and rework specifications for surface mount plastic packages such as PLCCs, PQFPs, and SOPs.

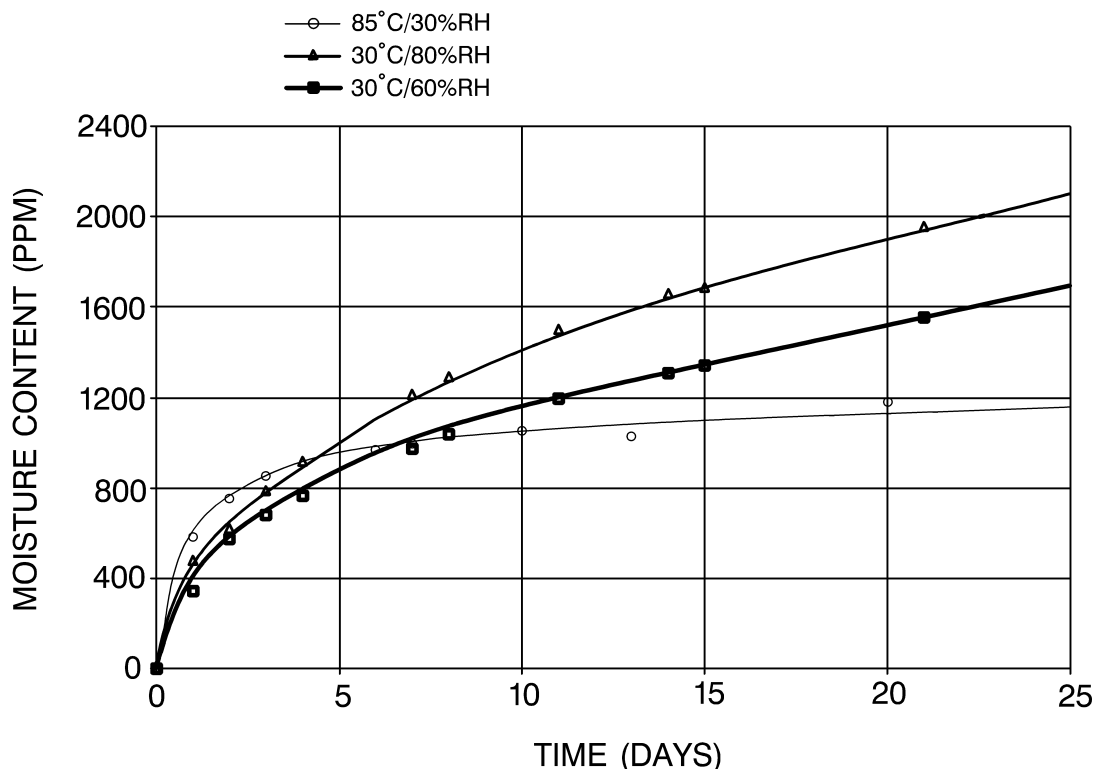
Problem Summary

Current plastic packages use various molding compound formulations consisting of epoxy resin, silica fillers, and other minor constituents. The epoxy resin is non-hermetic and absorbs a small percentage of moisture through diffusion. Eventually, an equilibrium develops between the moisture content inside the package and the ambient moisture and temperature conditions. If enough moisture is present in the package during surface mounting, the intense reflow heat turns the moisture into saturated steam (1). This extreme pressure, accompanied by a drop in flexural strength of the molding compound at temperatures reaching up to 240°C, may cause the package to fracture allowing the steam to escape (2). Once the fracture occurs and the steam has escaped, a greater threat now exists to the device. The fracture allows moisture and ionic contaminants such as sodium, potassium, or chlorine to infiltrate the plastic package, potentially causing corrosion, and eventually failure of the device. Therefore, moisture-induced cracking must be prevented in order to maintain the long-term reliability of surface mount plastic packages.

Moisture Absorption

Plastic packages and epoxy resins in general, absorb moisture from the ambient environment. The rate of moisture diffusion into and out of a package is determined by the temperature of the environment in which the plastic package is placed. The overall moisture content of the epoxy resin at saturation is mainly dependent on the percent relative humidity of the environment, and only slightly dependent on the temperature (3). Using the 28x28x3.4mm PQFP as an example, *Figure 1* shows that the moisture content of the package at extended times is dependant on the humidity, and that the initial rate of moisture absorption is dependant on the temperature.

Moisture Absorption (Continued)



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FIGURE 1. Moisture Absorption Profile for a 28 x 28 x 3.4mm QFP Surface Mount Plastic Package

Surface Mount Technology

INTRODUCTION

Once the packages are delivered to the printed circuit board (PCB) manufacturer, these packages are attached to the PCB and passed through a furnace to reflow the solder. Reflowing the solder mechanically secures the package to the printed circuit board, and ensures contact with the pads. There are two basic heating principles employed in furnace design.

VAPOR PHASE REFLOW

The first design to be used was the Vapor Phase Reflow (VPR) furnace. The vapor phase system uses a variety of fluorocarbon chemicals, which boil at specific temperatures dependent on the molecular weight of the fluorocarbon. The most commonly used fluorocarbon boils at 219°C. The concept behind the VPR furnace is to create a saturated vapor above the boiling fluorocarbon, and use the latent heat of vaporization of the boiling vapor to heat the packages as they pass through the vapor. Essentially, the vapor condenses on the plastic packages, and imparts the energy which is given up when the fluorocarbon changes phase from gas to liquid. The energy transfer in this process is very rapid, which accounts for the 10°C/sec. to 20°C/sec. temperature change in the packages.

CONVECTION REFLOW AND CONVECTION / IR REFLOW

The convection reflow furnace uses 100% convective heat transfer, whereas the convection / IR (infrared) furnace uses a combination of convection and radiant infrared energy to heat the parts. In both cases the parts are heated as they pass through the furnace on a belt. There are usually several heating zones, which can be individually controlled to give a desired time-temperature profile. These furnaces typically give temperature rate changes on the order of 1°C/sec. to 3°C/sec. As compared to the convection/IR furnace, the 100% convection reflow furnace gives a smaller temperature variation from package-to-package, for a given type of package, across the PCB.

Moisture-Induced Cracking Threshold

The moisture-induced cracking threshold refers to the moisture content necessary to cause a surface mount plastic package to crack under specified reflow conditions. Moisture diffuses into the plastic package, where it ultimately reaches an equilibrium with the environmental ambient. The packages are then placed into the solder reflow furnace causing the absorbed moisture to form saturated vapor. The expanding vapor creates internal pressure on the package and cracks it from the inside. The water vapor then escapes

Moisture-Induced Cracking Threshold (Continued)

through the crack relieving the pressure. The cracked package now has a direct path of moisture ingress into the package.

There are many factors to consider when determining the moisture-induced crack threshold of surface mount packages. Some of the more important factors are the moisture and temperature of the environment, the characteristics of the mold compound, the die attach paddle (DAP) size, the package thickness, and the lead frame material. The environment and the mold compound govern the rate of moisture absorption and final moisture content in the package. The DAP size and package thickness determine the ability of the package to sustain the pressure from the moisture vapor at solder reflow conditions. The lead frame material dictates the quality of adhesion to the molding compound.

Moisture Barrier Dry Packing

INTRODUCTION

Moisture-induced cracking in susceptible surface mount packages is a serious reliability problem that can cause device failures. As a solution to moisture-induced cracking, the susceptible surface mount packages are dry packed with desiccant (MIL-D-3464, Type 1 and 2), in moisture barrier bags (MIL-B-81705) that are virtually impermeable to water. This packing procedure allows the surface mount packages to remain dry when placed in inventory or shipping, and offers the printed circuit board manufacturer the flexibility to mount these packages within a specific time period without having to perform a drying operation.

The industry has defined several moisture sensitivity levels (MSL) which relate to the maximum allowable time that the parts can be exposed to ambient conditions after removal from the dry pack prior to solder reflow. The IC manufacturer determines the appropriate MSL by following a defined procedure such as given in J-STD-020 (IPC/JEDEC joint specification). This MSL and the corresponding maximum allowable exposure time (floor life) are included on the label which is printed onto the moisture barrier bag. The moisture sensitivity levels are given in *Table 1*. MSL level 1 does not require dry pack, whereas levels 2 - 6 all require dry pack.

TABLE 1. Moisture Sensitivity Levels

LEVEL	FLOOR LIFE	
	TIME	CONDITIONS
1	Unlimited	$\leq 30^{\circ}\text{C}/85$
2	1 Year	$\leq 30^{\circ}\text{C}/60$
2a	4 Weeks	$\leq 30^{\circ}\text{C}/60$
3	168 Hours	$\leq 30^{\circ}\text{C}/60$
4	72 Hours	$\leq 30^{\circ}\text{C}/60$
5	48 Hours	$\leq 30^{\circ}\text{C}/60$
5a	24 Hours	$\leq 30^{\circ}\text{C}/60$
6	Time on Label (TOL)	$\leq 30^{\circ}\text{C}/60$

DRY PACK PROCEDURE

After electrical testing, moisture sensitive plastic packages shipped in trays are stacked 10 high, plus a cover tray. The stack of trays is then secured by a plastic strap, and subsequently placed into the appropriate dry pack bag, along with four units of desiccant and one humidity indicator card. The dry pack bag is then evacuated and sealed at 70 psi of pressure, a temperature of approximately 150°C , and for a three second dwell time. Finally, the dry pack is visually checked for seal quality and for tears or other imperfections in the dry pack bag.

OPENING THE DRY PACK

Once the consumer receives the dry pack, the dry pack should not be opened until the packages are ready for surface mounting. The moisture barrier bag should then be cut as close to the seal as possible to allow for potential resealing using industry standard vacuum sealer. The humidity indicator card (HIC) should be noted for the amount of relative humidity present in the dry pack. In most cases, the HIC should read less than 10

relative humidity (see *Figure 2*). Once opened, the packages must be surface mounted before the floor life has expired, as indicated on the dry pack label (see *Figure 3*).

If the HIC indicates 20

or more, then the moisture barrier bag has most likely been torn and the moisture sensitive packages will have been exposed to the ambient environment. In this case the parts should be baked prior to reflow according to the instructions printed on the dry pack label (see *Figure 3*).

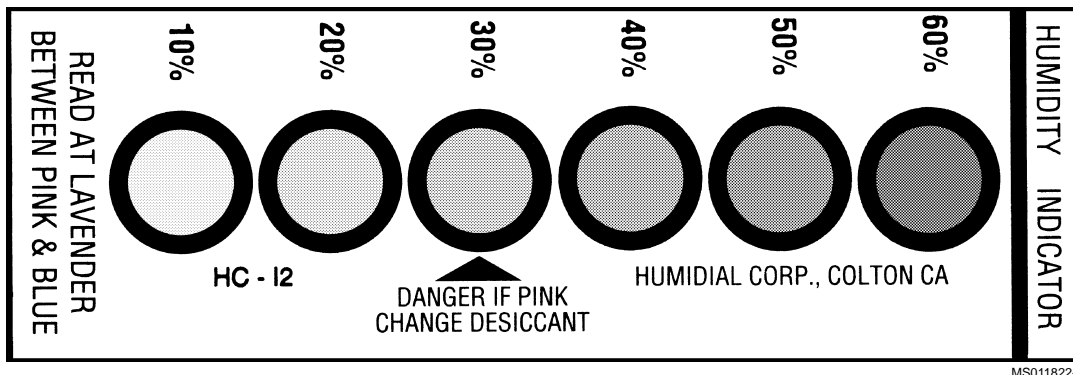


FIGURE 2. Humidity Indicator Card (HIC) Dry Packed with Moisture Sensitive Surface Mount Packages



CAUTION

**This bag contains
MOISTURE-SENSITIVE DEVICES**

LEVEL

3

1. Shelf life in sealed bag: 24 months at < 40 deg. C and < 90% relative humidity (RH)
2. After this bag is opened, devices that will be subjected to infrared reflow, vapor-phase reflow, or equivalent processing (peak package body temp. 220 deg. C) must be:
 - a) Mounted within 168 hours at factory conditions of <30 deg. C/
<60% RH,
OR
 - b) Stored at < 20% RH
3. Devices require bake, before mounting, if:
 - a) Humidity Indicator Card is > 20% when read at 23 +/- 5 deg. C, or
 - b) 2a or 2b is not met.
4. If baking is required, devices may be baked for:
 - a) 192 hours at 40 deg. C +5 deg. C/-0 deg. C. and <5% RH for low temperature device containers, or
 - b) 8 hours at 125 deg. C +/- 5 deg. C for high-temperature device containers.

Bag Seal Date: _____
(If blank, see bar code label)

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FIGURE 3. Dry Pack Warning Label for Surface Mount Packages

FLOOR LIFE

The Floor Life is the maximum time that moisture sensitive parts should remain under ambient conditions after the dry pack is opened prior to surface mount (see Table 1). Once the dry pack is opened, the packages absorb ambient moisture and will potentially crack during reflow if the Floor Life is exceeded. This Floor Life relates to the cumulative time the dry pack is open. For example, if the dry pack warning label indicates a 48-hour Floor Life, and the dry pack is opened for one hour to determine the dry pack contents, then the dry pack may be resealed using an industry standard vacuum sealer, discarding the old desiccant and replacing it with fresh, dry desiccant (Mil-D-3464, Type 1 and 2). The amount of Floor Life left is now 47 hours.

BAKING DRY PACKED PACKAGES

If the Floor Life is exceeded or the humidity indicator card reads greater than 20 relative humidity, the parts must be baked before surface

mount. Bake for 8-10 hours at 125°C in high temperature carriers, or for 192 hours at 40 °C and less than 5 RH in low temperature carriers. Once baked dry, the Floor Life is reset to that which is indicated on the dry pack label for the package under consideration.

When baking at high temperature, it is imperative that the trays are designated for high temperature use. If these tubes or trays are set for "low temperature," then baking at 125°C will cause the trays and tubes to warp. Therefore, it is recommended that the low temperature bake cycle be implemented when low temperature trays or tubes are provided. Transferring of packages to high temperature trays for the high temperature bake will potentially cause coplanarity problems with the leads. Finally, lead solderability can be degraded with successive bakes due to intermetallic formation at 125°C. Therefore, NSC recommends only 3 rebake steps at 125°C, but does not limit the number of times for low temperature rebake at 40°C.

PRINTED CIRCUIT BOARD DEMOUNTING

To remove solder reflowed surface mount packages from their printed circuit board, it is required to bake the entire board and package assembly either at 125°C for 8 hours or 40°C and < 5% RH for 192 hours to ensure that no package cracking will occur during the demount process. The bake cycle prior to package demount applies only to those packages which are moisture-induced crack sensitive.

REFERENCES

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2. M.P. Sepe, "Dynamic Mechanical Analysis Pinpoints Plastics Temperature Limits," *Advanced Materials & Processes*, pp 32–41, April 1992.
3. R. Lin, *et al.*, "Control of Package Cracking in Surface Mount Devices During Solder Reflow Process," *Proc. Int. Elec. Packg. Symp.*, pp 995–1010 (1987).

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