

MOISTURE SENSITIVE COMPONENT STORAGE

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ABSTRACT

Moisture Sensitive Devices (MSD) have become widely used with the increased sophistication of electronic products. However, MSDs present a number of challenges when used in surface mount assembly as they may suffer internal damage during the manufacturing process if they are not handled and stored according to industry standards.

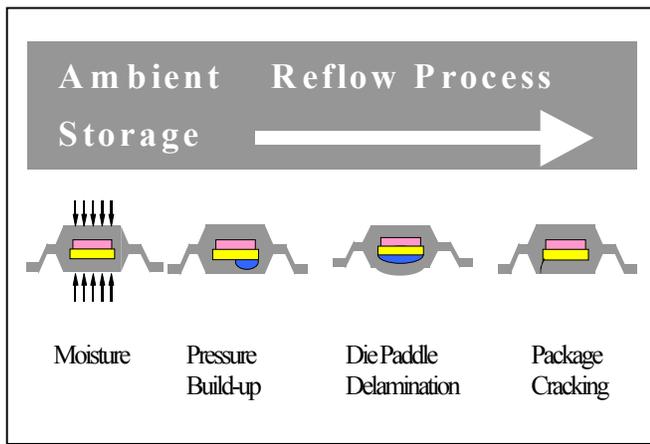


Figure 1

In surface mount assembly, solder paste is printed on to a PCB, components are mounted and the entire board is sent through a reflow oven. In the reflow process the entire PCB and component packages are heated along with the solder and component leads. The high reflow temperatures can cause a package containing moisture to swell and crack affecting the performance and reliability of the component. These problems are normally the result of poor handling and storage of MSDs.

While most of the damaged components may be detected prior to shipment of the final product, many make it to the market place only to fail out in the field. Although a component with external cracking may pass pre-shipment functional tests, subsequent high temperature and moisture exposure can induce the transport of ionic contaminants through these openings to the die surface increasing the potential for failure due to corrosion. Furthermore, internal cracking/delamination can be present even if there is no evidence of external cracks. Ball grid array (BGAs) and chip scale packages (CSPs) are especially sensitive to moisture and damage to these components can be very difficult to detect.

Manufacturers must pay close attention to their handling and storage of MSDs to maximize yields and ensure the

quality of their finished products.

Key words: Moisture-sensitive devices, moisture barrier bags, dry box.

WHY DO COMPONENTS REQUIRE LOW HUMIDITY STORAGE?

The plastic packaging used to manufacture surface mount devices (SMD) will absorb moisture from the atmosphere. The high temperatures involved in vapor phase/reflow soldering cause the absorbed moisture to expand rapidly, thus causing internal stress, known as “Popcorning.” Surface peeling between the die pad and the resin is caused by water vapor pressure during reflow. Surface delamination is likely, resulting in shear strain on bond wires and wire necking. Microcracking may extend to the outside of the package.

The SMT reflow process exposes devices to higher temperatures (220 to 235°C) than through-hole devices (135 to 150°C). The solder reflow processes of concern are convection, convection/IR, infrared (IR), vapor phase (VPR), and hot air rework tools. The use of assembly processes that immerse the component body in molten solder are not recommended for most SMD components.

Components are comprised of dies normally made of silicon, a die pad made from 42 alloy and various plastic materials which make up the body of the component. The materials that comprise a component have different thermal expansion ratios, adhesive strength and material strength characteristics. Thus, as illustrated Figure 1 above, moisture absorbed by components vaporize during the reflow process. The vapor pressure causes delamination

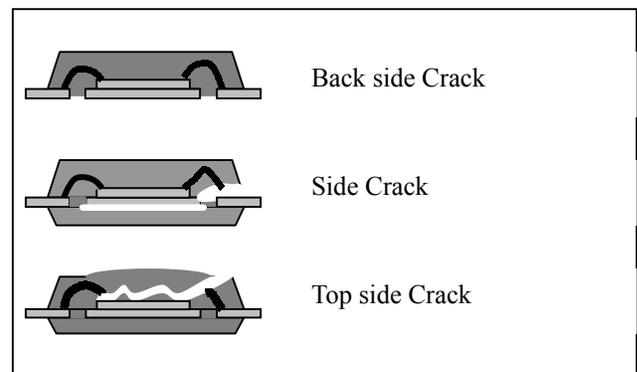
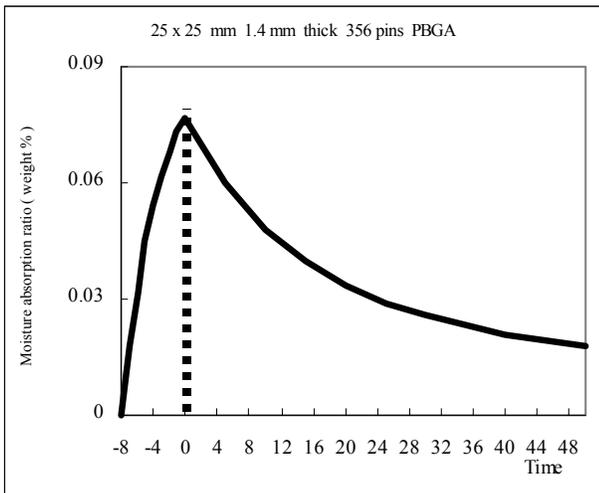


Figure 2 [1] : Component cracking

and cracking in the plastic component package.

External cracking may appear on the side, top and bottom side of components. As the package wall is often thinnest below the die pad bottom side cracking is the most common and very difficult to detect visually. Externally cracked components can suffer additional damage due to moisture, heat and vibration out in the market place. Internally the vapor pressure can create a void allowing the die paddle to move during temperature cycling. Surface delamination is likely, resulting in shear strain and breakage of bond wires.



IPC/JEDEC STANDARD J-STD-033

The guidelines of classification, handling and packing are

Figure 3: Component Dehumidification

clearly defined in the IPC/JEDEC Standard J-STD-033 - Standard for Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices.

This standard defines the standardized levels of floor life exposure for moisture/reflow-sensitive SMDs along with the handling, packing and shipping requirements necessary to avoid moisture-reflow-related failures. Companion documents, J-STD-020 defines the classification procedure, and JEP113 defines the labeling requirements.

Post Exposure to Factory Ambient Conditions

The standard defines the guidelines of classification, handling, drying and packing of Moisture/Reflow Sensitive surface Mount Devices.

Moisture sensitive components which have been exposed only to factory ambient conditions of $\leq 60\%$ RH for any length of time may be adequately dried by high or low temperature baking prior to reflow or prior to dry pack. Adequate baking resets the floor life clock, however, it can be a very costly and time consuming process. IPC Standards requires level 4 components (72 hours floor life at $30\text{ }^{\circ}\text{C}/60\%$ RH, which make up a majority of Plastic Ball Grid Array, PBGA) ≤ 2.0 mm thick to be baked for 31

hours at $125\text{ }^{\circ}\text{C}$ or for 43 days at $40\text{ }^{\circ}\text{C}$, $\leq 5\%$ RH. Most of Moisture/Reflow Sensitive surface Mount Devices Level 2a through 5a between 2.0 ~4.0mm in thickness are required to be baked for 48 hours at $125\text{ }^{\circ}\text{C}$, or for 67~68 days at $40\text{ }^{\circ}\text{C}$, $\leq 5\%$ RH.

The need for component baking can result in decreased productivity in high mix production. The baking schedule must also ensure that components are available prior to assembly. Heating of components in the baking process can increase the oxidation of leads and result in poor solderability.

High temperature baking of tape and reel components is extremely costly and time consuming. As tape and reel configurations can not withstand high bake temperatures, the components must be removed from the carrier package, baked, then placed back into the tape and reel configuration.

Short Duration Exposure

Baking components according to IPC specifications can be costly and adversely affect production and productivity. Manufacturers may be able to avoid the baking process for left over components used in small production runs by following IPC Specifications for short duration exposure.

Previously dry components that have been exposed only to factory ambient conditions not exceeding $30\text{ }^{\circ}\text{C}/60\%$ RH for less than eight(8) hours can be adequately dried by room temperature desiccation. A minimum desiccating period of 5X the exposure time is required to dry the components enough to reset the floor life clock. Thus, a maximum of 40 hours (5 x 8 hours) is required for component drying according to this method. Furthermore, as components are not subjected to the higher temperatures used in baking,



there is reduced risk of lead oxidation. IPC Specifications present three options for room temperature desiccation.

- **Moisture Barrier Bags (MBBs)**

Moisture sensitive components must be placed in a Moisture Barrier Bag (MBB) with a fresh desiccant and RH indicator. The moisture barrier bag is then sealed and a caution or bar code label is placed on the MBB. The amount of desiccant used shall be calculated according to the bag surface area and water vapor transmission rate in grams/100 in² in 24 hours in order to maintain an interior relative humidity in the MBB of less than 10 % at 25 °C.

➤ **Nitrogen Cabinet**

Moisture-sensitive components are placed in a Nitrogen Cabinet capable of maintaining less than 10 % RH and 25 °C +/-5 °C. Nitrogen cabinets must be set up so that an appropriate flow of nitrogen forces out all moisture and contamination. Nitrogen has a lower specific gravity than air, and is introduced in the upper section of the desiccator. The heavier air is then purged out from the bottom. Some nitrogen boxes are made of plexiglass and other hygroscopic plastics that will absorb moisture from the outside and pass it into the box. The higher the difference between the external and internal humidity levels, the more nitrogen is needed in order to remove any moisture that passes through the desiccator wall.



➤ **Dry Air Box (Desiccated Cabinet)**

Moisture sensitive components are placed in a dry box (desiccation system is used) capable of maintaining less than 10%RH and 25°C +/-5 °C. Zeolite and silica gel are the most common desiccants used in dry air boxes.

Absorption ratio

The time constraints by which a component must be mounted after removal from a MBB is clearly stated in IPC/JEDEC STANDARD J-STD-033. Components exposed to floor conditions under 8 hours can be dried by room temperature desiccation, however, baking is required for components that exceed the 8 hour limit. What is the relationship between time, component moisture absorption and component damage? Figure 4 displays one example of

the cracking point of a SOP that has been baked then humidified. Cracking occurred in the SOP when the component absorbed more than approx 0.15% of its weight in moisture. This is only one example and caution must be taken as components will crack at different absorption rates depending on its size, material and design.

Furthermore, cracking will occur at different moisture absorption ratios depending upon whether it is being humidified or dehumidified. Figure 5 below displays (1) the point at which a component cracks as it is being humidified from a dry state (2) the point at which the component continues to crack as it is being dehumidified after absorbing moisture.

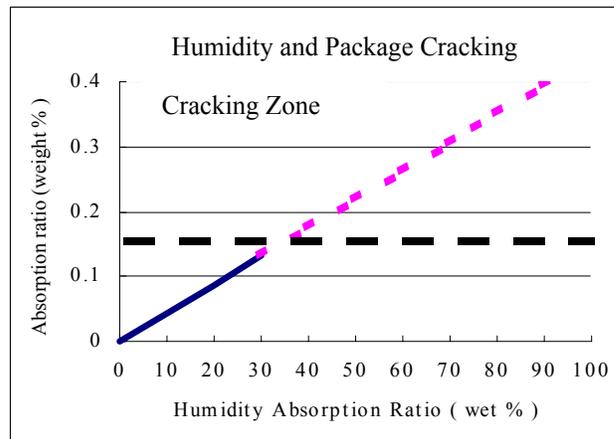


Figure 4 [2]:Humidity and Package Cracking of SOP Component (85 °C)

Components which were completely dried by the baking process then humidified at 85%RH did not show cracking until they had absorbed approx 0.25%(wt) of moisture. However, components which had absorbed moisture over a considerable amount of time then dehumidified, continued to show cracking until they were dried by the baking process to a point below 0.1%(wt).

Components removed from their MBB begin absorbing moisture from the atmosphere. At first the plastic packaging absorbs the moisture and it slowly spreads to the chip and die pad. Moisture that reaches the die pad expands rapidly during the reflow process causing delamination and package cracking. This is due to the different materials used at the center of the package. Cracking will not occur if moisture is absorbed only by the plastic packaging. Thus, the moisture absorption time of a component is extremely critical.

Room Temperature Dessication

It is very clear from the above component moisture absorption ratio, time and cracking data that proper handling of components is critical. Components that have been exposed to factory ambient conditions for longer than 8 hours must be baked, however IPC Specifications allow

for different methods to be used for room temperature desiccation.

When using Moisture Barrier Bags (MBBs), the components and carrier package are inserted into the bag along with an RH indicator card and a desiccant often made of silica gel. The MBB is then heat sealed. The silica gel desiccant must be able to reduce the RH level within the bag to below 10%RH. Silica gel is a reversible desiccant material that will absorb moisture when it is dry, but will

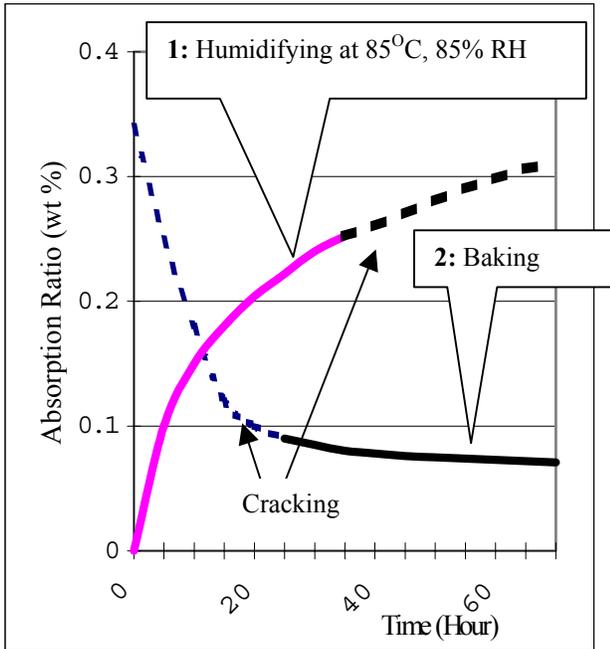


Figure 5 [3]: Package Cracking Humidifying & De-humidifying (Baking) of Components

also emit moisture if the surrounding environment is relatively drier than the silica gel seeking a state of equilibrium. In an environment of 10%RH silica gel will hold moisture at approx 5.5% of its weight. The main concern with MBBs is operator handling error. After components are removed from the SMT line they are often stacked in an area dedicated for resealing. Components must be resealed promptly, desiccant must be fresh, re-used MBBs should be checked for any possible damage and finally the resealed components must be properly labeled to indicate when the components will be ready for use again.

Caution should be taken to ensure that a sufficient amount of desiccant is used in the MBB according to IPC Specifications. The amount of desiccant required is based on the required shelf of the components, water vapor transmission rate of the MBB, total surface area of the MBB and the amount of water in grams that the desiccant will absorb at 10%RH.

In order to achieve 10%RH in a MBB given a factory environment of 25°C, 60RH the following amount of silica

gel is required.

$$\begin{aligned} \text{Saturated Vapor Pressure at } 25^{\circ}\text{C} &= 23 \text{ g} / \text{m}^3 \\ \text{Vapor Pressure at } 25^{\circ}\text{C, } 60\% &= 23 \text{ g} / \text{m}^3 \times 60\% \\ &= 13.8 \text{ g} / \text{m}^3 \\ \text{Vapor Pressure at } 25^{\circ}\text{C, } 10\% &= 23 \text{ g} / \text{m}^3 \times 10\% \\ &= 2.3 \text{ g} / \text{m}^3 \end{aligned}$$

A MBB with dimensions of 20 x 40 x 4 cm (7.87 x 15.75 x 1.57 in) has a volume of 0.0032m³. Accordingly the amount of moisture vapor that must be absorbed by the desiccant in the MBB becomes (13.8 - 2.3 g / m³) x 0.0032 m³ = 0.0368 g.

As silica gel will only hold 5.5% of its weight in water at 10%RH, a total of 0.66g (0.0368g / 5.5 % = 0.66g) is required.

According to the above calculations 1g of silica gel would be sufficient. However, a new package of silica gel desiccant will not be 100% dry prior to insertion and may have 1-2% moisture(wt). Furthermore, the tape, reel and trays which hold the components can also contain water vapor. A typical tray may hold 3g/m³ of water vapor. If we take these factors into account along with the need to reduce the RH level within the MBB to 5% RH to ensure that IPC specifications are met, our calculations become as follows:

$$\begin{aligned} \text{Vapor Pressure at } 25^{\circ}\text{C, } 60\% &= 23 \text{ g} / \text{m}^3 \times 60\% \\ &= 13.8 \text{ g} / \text{m}^3 \\ \text{Vapor Pressure at } 25^{\circ}\text{C, } 5\% &= 23 \text{ g} / \text{m}^3 \times 5\% \\ &= 2.3 \text{ g} / \text{m}^3 \\ 13.8 \text{ g} - 2.3 \text{ g} + 3\text{g} &= 14.5\text{g} \end{aligned}$$

$$14.5\text{g} \times 0.0032\text{m}^3 = 0.0464\text{g}$$



According to the above calculations the desiccant must absorb 0.0464 grams of vapor moisture to account for the moisture in the MBB and tray to achieve 5%RH. Given that a silica gel desiccant pack can absorb approximately 5% of its weight in moisture at 5%RH and that it is 2%

saturated prior to usage, a minimum of 1.55 grams of silica gel is required.

Lastly, the water vapor transmission rate (WVTR) of the MBB as well as the required length of storage must be factored into the amount of desiccant required. Given a WVTR of 0.005g per 100in²/24hr and MBB surface area of 248 in², 4.526 g of moisture will enter the bag every 365 days. Accordingly, 12 months of storage will require an additional 82.3 grams of silica gel desiccant.

Dry Boxes are an alternative to MBBs that can greatly reduce operator handling error assuming that the placement of components in a dry box is less tedious and time consuming than resealing. However, Nitrogen Dry Boxes require that a facility has N₂ supply and may incur large running costs. Furthermore, a properly calibrated RH meter should be used with N₂ Dry Boxes to help regulate gas flow. It is incorrect to assume that simply supplying N₂ gas into an enclosed cabinet without proper monitoring will achieve required RH levels. Caution must also be taken to avoid over pressurizing the cabinet.

Nitrogen boxes made of plexiglass and other hygroscopic plastics will absorb moisture from the out side and pass it into the box. Thus, even a perfectly sealed N₂ Box requires constant gas flow to purge moisture vapor that enters through the box walls. The higher the difference between the external and internal humidity levels, the more nitrogen is needed in order to remove any moisture that passes through the desiccator walls. A N₂ box in an extremely humid area such as Florida will require a faster gas flow rate than an N₂ box in a dry region in Arizona in order to maintain the same RH levels.

Air Dry Boxes which utilizes a very strong desiccant are popular in Asia due to the extreme humidity in the region and high cost of nitrogen. Normally the desiccant is recycled automatically with a heating mechanism and does not require replacement. Performance of Air Dry Boxes is based on the type and amount of desiccant used, efficiency of the desiccant recycling system and sealing of the cabinet. Two types of desiccant, silica gel and zeolite are commonly

used. Of the 2, zeolite is greatly more efficient at lower RH levels. Figure 6 displays the percentage of moisture by weight that silica gel and zeolite can hold at 25°C and varying RH levels.

At 25°C, 5%RH zeolite can hold 20% of its weight in water compared to only approx 5.5%(Wt) for silica gel. To bring a 2m³ (35f³) container at 25°C, 60%RH to a level of 5%RH 23.0grams of moisture must be removed from the air. This can be accomplished using 115g of zeolite or 418g of silica gel.

When using N₂ or Air Dry boxes caution must be taken to ensure that the doors are not opened too frequently and for extended periods time such that the RH level with in the dry box become unstable.

CONCLUSION

Improper storage of moisture sensitive components can lead to low yields and product failures out in the market place. Combined utilization of MBBs and Dry Boxes can help manufacturers effectively and efficiently implement proper handling procedures based on IPC/JEDEC specifications. MBBs and Dry Boxes present an alternative to baking components which have been exposed to factory ambient conditions less than 8 hours. Dry Boxes are a good option for components that require short term storage at low RH levels. MSDs which must be used shortly after baking can be easily staged in dry boxes. Dry boxes are also convenient for MSDs to be used for rework. Rework operators are able to remove the required number of components from a dry box and are relieved from constantly having to reseal the remaining MSDs. MBBs may be more practical for components that require extended storage time due to the limited storage space in Dry Boxes.

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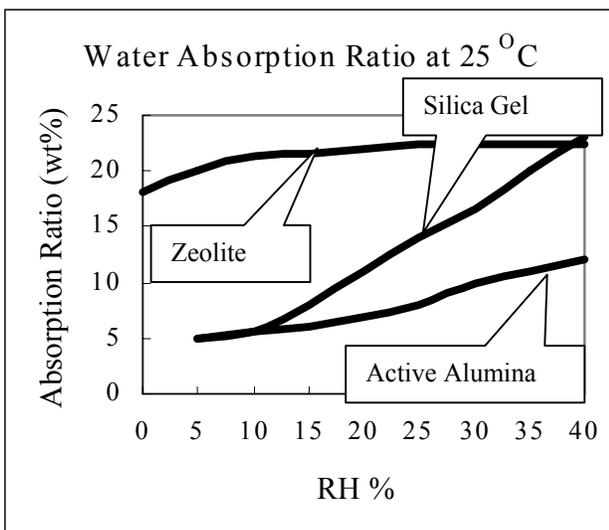


Figure 6 [4]: Water Vapor Absorption Ratio