Pulse
A TECHNITROL COMPANY

MOISTURE CONTROL MEASURES

for
Epoxy Encapsulated Surface Mount Magnetic Components

Extending Pulse's Commitment to a Quality Partnership

© 1996, Pulse Engineering, Inc.

Pulse
A TECHNITROL COMPANY

The Situation

Over the past decade, the transition from through-hole to SMT production techniques has revealed quality problems that result from moisture absorption in plastic encapsulated semiconductors. The temperatures involved in SMT reflow soldering (210°C to 250°C) can cause trapped moisture to rapidly expand, thereby physically damaging the component. To counter these problems, the IPC and EIA/JEDEC standards groups have established extensive guidelines for characterizing IC moisture sensitivity and for controlling moisture content via dry-packing and handling procedures.

The Challenge

While these guidelines do not currently encompass non-IC components, independent studies conducted by Pulse have shown that epoxy encapsulated SMT magnetic components exhibit the same types of internal delamination and package cracking as ICs. Pulse has also observed the tendency for moisture expansion to cause epoxy encapsulated packages to bulge. Such bulging during the reflow solder process can sometimes lift leads from the PCB, thereby causing open solder joints even though the component itself is still functional.

The Opportunity

Pulse has proactively extended the existing IPC and JEDEC standards for IC moisture characterization and dry-packing to all of their epoxy encapsulated SMT magnetic components. Because SMT manufacturers are familiar with the industry-accepted procedures for handling dry-packed ICs, they can readily adapt their existing processes to include handling SMT magnetics as well.

The Benefits

Pulse's empirical studies have shown that most of the post-reflow epoxy encapsulated SMT component failures currently experienced by system manufacturers can be eliminated through the rigorous prevention of moisture absorption. By using their existing moisture control procedures for handling Pulse's dry-packed SMT magnetic components, Pulse's customers can achieve significantly higher yields, reduce costly rework and provide improved quality levels to their end users.

Situation Overview

As the electronics industry has transitioned from traditional through-hole technologies to Surface Mount Technology (SMT) manufacturing, one of the issues which has come to the forefront is maintaining component integrity throughout the high temperatures associated with SMT solder reflow processes (SRP). Wave soldering techniques traditionally used for through-hole assemblies avoided heat damage to the component bodies because the molten solder wave simply wicked onto the leads protruding through the underside of the PCB. However, with SMT components, the entire assembly is placed into reflow ovens where the temperature is raised close to the solder's melting point and then spiked up to liquefy the solder and create the connections between SMT component leads and the PCB. Typical temperature peaks in today's SMT reflow ovens range from 210° to 250° C, which creates a number of problems for component survivability.

© 1996, Pulse Engineering, Inc.

Thermal-Damage Issues in SMT Processes

Over the past seven years, the semiconductor manufacturing industry and the designers/manufacturers of SMT assemblies have done extensive research and development to characterize and resolve the SRP temperature-induced component failures arising from the changeover to SMT processes. Major problem areas that have been identified are the cracking of the components' protective packaging and/or stress damage to the internal electrical connections within the component.

Such component damage is usually due to internal physical stresses caused by significant differences in the thermal expansion characteristics of the various components used in the semiconductor, its lead-frame and the plastic packaging surrounding them. (The Coefficient of Thermal Expansion (CTE) for silicon is approximately 4-5 ppm/°C, while the plastic encapsulant is 22 -23 ppm/°C, and the conductive metals used in the lead frame and bond wire range between 14 and 19 ppm/°C.)

Over the years, semiconductor manufacturers have developed sophisticated design techniques for understanding and managing these internal differences in CTE to avoid undue design-related stresses that can damage the ICs. However, one additional factor also must be controlled to ensure that even well-designed components do not fail during the solder reflow process. This additional factor is the natural tendency of plastic-encapsulated components to absorb moisture from the environment (Ref. IPC-SM-786A). Rapid thermal expansion of the entrapped moisture can significantly damage the component.

According to the Electronics Industry Association:

> *Moisture sensitivity of plastic surface mount devices is a major quality and reliability concern for both semiconductor manufacturers and OEMs. Moisture inside a plastic package turns to steam and expands rapidly when the package is exposed to the high temperature of VPR (vapor phase reflow) or IR (infrared) soldering. Under certain conditions, the force from this expanding moisture can cause internal mechanical damage and device failure. In the most severe cases, the stress can result in external package cracks. This is commonly referred to as the "popcorn phenomenon" because the internal stress causes the package to bulge and crack with an audible "pop". (Ref.: JEDEC JESD22-A112, pg.1)*

In addition to the internal delamination and package cracking described above by the EIA, Pulse has also observed the tendency for moisture expansion to cause epoxy encapsulated packages to bulge. Such bulging during the reflow solder process can sometimes lift leads from the PCB, thereby causing open solder joints even though the component itself is still functional. It is believed that a significant percentage of customer returned components that subsequently test as functional may result from this phenomena.

Dry Packing Objectives

Dry packing techniques focus on reducing the incidence of moisture-related thermal damage by

1) characterizing a component's susceptibility to moisture absorption; and

2) instituting rigorous procedures to control exposing susceptible components to environmental conditions that promote moisture absorption. (Ref. IPC-SM-786A)

The characterization process is designed to collect information about how quickly the components will absorb potentially damaging moisture under specifically defined conditions. Once the profile has been empirically established, the component is assigned to one of six IPC standard categories (Ref. IPC-SM-786A pg. 3). The categories are intended to be used by IC producers to inform IC users of the level of moisture sensitivity for each of their components and/or component families.

© 1996, Pulse Engineering, Inc.

The procedures for controlling environmental exposure are rigidly defined for each of the six categories, detailing whether or not dry packing is required and what types of packaging and desiccant materials are to be used to protect susceptible components. The handling procedures also specify how many hours of "out-of-the-bag" exposure at the SMT manufacturer's site is acceptable for each category level of dry-packed components prior to putting them through the reflow processes. The handling procedures are intended to ensure proper precautions are applied to all components based upon their empirically measured moisture susceptibility levels.

For semiconductors, the dry packing characterization and exposure-control process has helped to significantly reduce the incidence of moisture related damage (Ref. *J. Maxwell, SMT Magazine, July 1990, "Temperature Profiles: The Key to SMT Assembly Process Control")*. This is due in large part to the wide acceptance and understanding of the dry-packing and handling procedures by both semiconductor suppliers and SMT manufacturers. Characterization and dry-packing alone would accomplish little if the manufacturers failed to maintain disciplined procedures for limiting exposure times in the warehouses and factory environments. While the dry-packing procedures, as currently accepted, only encompass SMT semiconductor components, the handling disciplines employed by manufacturers can easily be extended to cover other SMT components, such as magnetics, as long as equivalent characterization methods and category assignments are used.

Applicable Procedures & Industry Standards

Comprehensive industry standards which define dry-pack testing, characterization and handling-procedures have been developed and adopted by both the IPC (Institute for Interconnecting and Packaging Electronic Components) and EIA (Electronic Industries Association) JEDEC Council (Joint Electronic Device Engineering Council). The directly applicable documents include:

IPC-SM-786

Impact of Moisture on Plastic IC Package Cracking

IPC-SM-786A

Procedures for Characterizing and Handling of Moisture/Reflow Sensitive ICs

IPC-4202

Assembly Process Preconditioning for Qualification of Components

JEDEC Standard JESD22-A112

Moisture Induced Stress Sensitivity for Plastic Surface Mount Devices

JEDEC Standard JESD22-A113

Preconditioning of Plastic Surface Mount Devices Prior to Reliability Testing

© 1996, Pulse Engineering, Inc.

While there are some variations between the specific provisions of the IPC and JEDEC standards, they are in agreement on all of the major aspects of characterizing components and controlling exposure. (According to Ray Prasad, Chairman of the IPC 786 Committee, preliminary discussions have begun to align the existing standards into a single document, tentatively called J-Standard 20.) For purposes of simplicity, the following discussion provides an overview of the dry-pack testing, characterization and exposure control processes that takes into account the common thrust of all the above listed standards.

Classification Categories

The six JEDEC Moisture Sensitivity categories are intended to define the length of time that a component can be exposed to typical shop floor environmental conditions before absorbing enough moisture to reach a threshold level of potential damage during the reflow process. Studies have shown that this threshold level for plastic encapsulated parts is a moisture content of approximately 0.10% by weight. Exposure time is defined as the time a part takes to go from completely dry to its threshold moisture level, in an environment of 30°C and 60%Relative Humidity. The categories and their respective exposure times are as follows:

JEDEC Moisture Sensitivity Levels		
Level	**Description**	**Exposure time at 30°C/60%RH**
1	Non-Moisture Sensitive	Unlimited
2	Limited Moisture Sensitivity	1 Year
3	Moisture Sensitive	1 Week (168 hours)
4	Very Moisture Sensitive	3 Days (72 hours)
5	Highly Moisture Sensitive	1 Day (24 hours)
6	Extremely Moisture Sensitive	None (Requires Baking Prior to Use)

Dry Packing Materials and Methods

Those components which are classified in Levels 2-5 require dry packing to protect them from exposure to moisture during shipment and storage prior to usage in the assembly process.

The component manufacturers' responsibilities for dry packing include:

- Baking the components to ensure that they are "dry"
- Packing the components with approved Desiccant Materials in Moisture Barrier Bags and including Humidity Indicator Cards in the bags to help track device exposure levels.
- Properly labeling moisture susceptible components

© 1996, Pulse Engineering, Inc.

Desiccant Materials, Moisture Barrier Bags & Humidity Indicator Cards

A “dry pack” consists of desiccant material and a Humidity Indicator Card (HIC) sealed with the components inside a Moisture Barrier Bag (MBB).

The protective moisture bag should meet MIL-STD-81075 TYPE 1 requirements for flexibility, ESD protection, mechanical strength and puncture resistance. MBBs should be heat sealable and have a Water Vapor Transmission Rate (WVTR) of less than 0.02 gm/100 sq. in./24 hours at room temperature.

The Desiccant Material should meet MIL-D-3464, TYPE II absorption specifications and should be dustless, and non-corrosive. The amount of desiccant used is based on the surface area and WVTR of the MBB in order to maintain an interior relative humidity of less than 20%RH at 30°C ambient temperature.

The Humidity Indicator Card serves as a guide to monitoring device exposure. The HIC should have at least three color-change moisture-sensitive indicator dots graded at 10%, 20% and 30% humidity levels. If the 20% indicator, or 20% & 30% indicators, have turned from blue to pink, it is an indicator to the user that the dry pack has expired and/or been exposed to excessive moisture and should not be used without baking.

Labeling of Moisture Sensitive Components

In order to assist SMT manufacturers in proper component handling and storage. Dry packed moisture sensitive components must also have a warning and information labels affixed to the outside surface of the bag. The Moisture Sensitive Identification Label informs the user of the components’ level of sensitivity, the manufacturer’s “factory seal date”, and provides the user with an activity log to monitor periods of exposure and to calculate remaining shelf life. The Caution Label outlines precautions that should be taken when handling desiccant packed components.

Example of Pulse Moisture Sensitive Identification Label

CAUTION

This bag contains

MOISTURE-SENSITIVE DEVICES

LEVEL **4**

1. Shelf life in sealed bag: 12 months at <40°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°C) must be:
   a) Mounted within 72hours at factory conditions of ≤30°C/60% RH, or
   b) Stored at ≤20% RH.
3. Devices require baking, before mounting, if:
   a) Humidity Indicator Card is >20% when read at 23°C ± 5°C, or
   b) 2a or 2b is not met.
4. If baking is required, devices may be baked for:
   a) 192 hours at 40°C + 5°C/–0°C and <5% RH for low-temperature device containers, or
   b) 24 hours at 125°C ± 5°C for high-temperature device containers

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

Note: LEVEL defined by EIA JEDEC Standard JESD22-A112

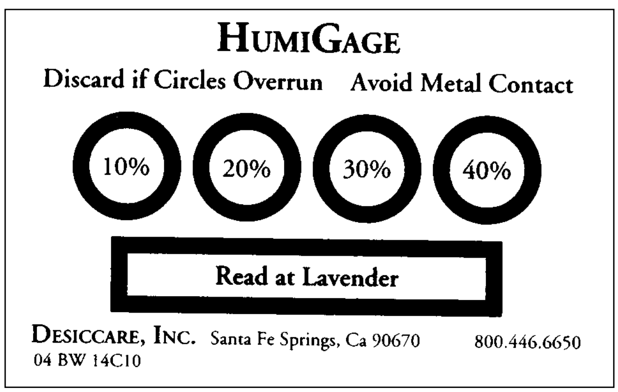
© 1996, Pulse Engineering, Inc.

Post Shipment Handling Procedures

To be effective, the dry packing program must be a partnership between the component supplier and the SMT manufacturer. When handling moisture sensitive components, users at SMT assembly sites must maintain the integrity of the moisture protection system in order to avoid the potential for moisture-related damage during the reflow soldering process. Handlers must ensure that the bag is properly sealed after each use and that each bag contains its HIC. Prior to using the contents, the handler must verify that the HIC indicates an acceptable humidity level and that the total exposure time recorded on the bag does not exceed the components' classification level.

When accessing the components, the handler should record the date, the period of time during which the bag was open, and the humidity level. During board assembly, the "out-of-bag" exposure times must controlled to ensure that they do not exceed the limits for the specified category level. Manufacturers must ensure that unused components are immediately re-bagged to limit exposure. For those manufacturers that have existing nitrogen chambers, they can also be used to store partially-used bags under low humidity conditions. When the monitoring log and/or HIC indicates that exposure time limits have been exceeded, the SMT manufacturer should re-bake the components (at 125° C for 24 hours) to ensure dryness prior to usage.

Example of Pulse Humidity Indicator Card



Industry Expectations with Regard to IC Dry Packing

From a pragmatic standpoint, SMT manufacturers have almost universally adapted to the routine usage of dry-packed IC components. While the additional in-house handling procedures do involve significant cost and time on their part, the alternatives to the use of dry packed ICs are in most cases unacceptable. The costs associated with re-working functionally defective, cracked and/or "popcorned" components greatly out-weigh the cost of properly handling MBB dry packs and closely monitoring moisture exposure levels.

The other alternative, that of pre-baking all components prior to usage in the SMT assembly process, was used as an interim solution by many manufacturers prior to the development of the dry packing standards, and it too was found to be too costly for a number of reasons. First it often required the manufacturer to make an additional capital investment in the ovens, trays etc. required for routinely baking high volumes of components. Secondly, it ran the risk of introducing other problems into the ICs, such as coplanarity and/or ESD damage during this extra handling of the individual parts. The costs and risks were too high for such secondary operations as removing components from their factory packaging (e.g. tape & reels, tubes, etc.), placing them in baking ovens, and then returning them to packaging that could be used in automated processes. Additionally, because standard procedures for baking had not yet been established, baking by the users created the possibility for warranty finger-pointing between users and component suppliers.

© 1996, Pulse Engineering, Inc.

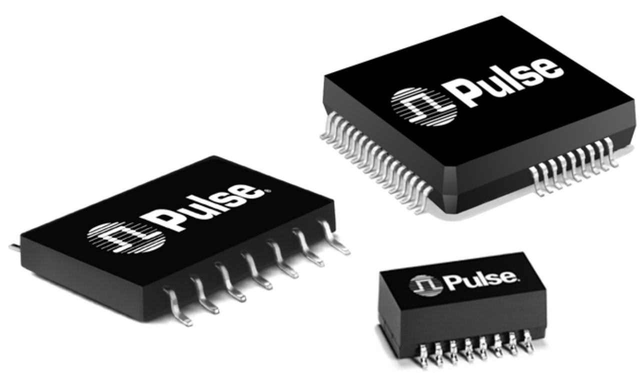
Today, with the wide-spread standardization of procedures for dealing with moisture sensitivity, many SMT manufacturers routinely include requirements for dry-packing as part of their procurement specifications. According to Ray Prasad, Chairman of the IPC 786 Committee, and author of *Surface Mount Technology: Principles and Practice,* "the awareness and acceptance of moisture profiling and dry-packing has led most SMT manufacturers to see it as an almost mandatory practice that they expect from their suppliers."

Pulse's Research on Dry Packing for Encapsulated SMT Magnetics

Traditionally, most suppliers of non-IC SMT components have routinely believed that moisture susceptibility was not an-issue for their industry segments. The less fragile nature of most non-IC, epoxy encapsulated, SMT components and the lack of internal die delamination as a potential failure led many suppliers to discount the possibility of moisture related damage occurring with their products during reflow. As an acknowledged leader in the magnetics industry for both quality and technology, Pulse believed that the issue deserved a thorough investigation to determine its possible potential for reliability improvement.

During the past year, Pulse has worked closely with its major customers, reviewed relevant field data and conducted empirical research to evaluate the need for adopting moisture characterization and dry-packing for its epoxy encapsulated, SMT magnetic products.

Expanding from specific data provided by customers, Pulse quality and process control staff developed a series of experiments that indicated a real potential for improving overall reliability by controlling moisture absorption in magnetic components. These experiments addressed a range of different package types, including quad flat-pack (QFP), PCMCIA thin packages, and standard SMT DIP IC-like packaging as shown below:



The first step in Pulse's research was to expose various product samples (drawn from customer-returned stock and from Pulse inventory) to reflow solder temperatures to determine base line failure rates. Subsequent testing was conducted on similar component samples which had been pre-baked to remove all moisture prior to testing.

Consistent results across the various package-types have indicated that the elimination of absorbed moisture from epoxy encapsulated SMT magnetic products can reduce post-reflow solder failure rates by as much as 93%.

© 1996, Pulse Engineering, Inc.

Benefits of A Comprehensive Dry Packing Program

Based upon these preliminary results, Pulse conducted full testing and characterization of all their epoxy encapsulated SMT magnetic products using the IPC/JEDEC procedures. Pulse then implemented post production baking and dry pack for all epoxy encapsulated SMT products. The benefits of instituting this comprehensive testing and dry-packing program have included:

- Direct cost savings for Pulse and its customers from improved quality and lower warranty expenses
- Improved relationships between Pulse and its customers
- Extension of Pulse's reputation for industry leadership in both quality and technology

SMT manufacturers have come to expect their IC suppliers to conform to rigorous procedures for testing the moisture sensitivity of their components. Such compliance is seen as a commitment on the part of the vendor to assist the SMT manufacturer in controlling the production processes and achieving the highest possible quality levels. Even though the "requirement" to address moisture sensitivity issues has not yet been extended to the magnetics industry, Pulse has chosen to "set the example" by proactively instituting a comprehensive testing and dry-packing program.

Because SMT manufacturers are familiar with the industry-accepted procedures for handling dry-packed ICs, they can readily adapt their existing processes to encompass handling SMT magnetics as well. By using their current moisture control procedures for handling Pulse's dry-packed SMT magnetic components, Pulse's customers can achieve significantly higher yields, reduce costly rework and provide improved quality levels to their end users.

Pulse Dry-Packing Program Implementation

Today all package types of Pulse SMT pour-filled and transfer-molded products have undergone the characterization process as outlined by the IPC and JEDEC standards. The majority of the products have been rated in the Level 3 Moisture Sensitivity Category, which requires dry-packing and control of exposure time to a maximum of 168 hours prior to usage by the SMT manufacturer. A few products have been characterized as Category 4, which requires a maximum exposure time of 72 hours prior to usage. ECNs have been written and implemented to bake and dry-pack all Pulse epoxy encapsulated SMT products.

Procedures, equipment and training are in place to conduct dry-packing operations at all Pulse manufacturing and shipping facilities. The Pulse dry packing process is controlled by Pulse Procedure P-21373. The overall processes are designed to control MET (Manufacturer Exposure Time) to less than 24 hours between the production-level component baking operation and completion of the dry-packing operation.

Pulse Quality Control, Sales and Customer Support staff have working with Pulse customers on mutual implementation of the moisture control and dry-packing procedures. The uniformly consistent response from customers has been a positive reaction to Pulse's proactive establishment of a dry packing program for epoxy encapsulated SMT products.

Summary

Empirical evidence now indicates that, contrary to traditional assumptions, epoxy encapsulated magnetic components can experience significant moisture related damage during the high temperatures associated with solder reflow processes. Additional tests and field experience with Pulse customers have proven that dry-packing, after the components have been production-baked to eliminate moisture, can greatly reduce the incidence of moisture damage.

Industry-wide accepted IPC and JEDEC standards for IC moisture characterization and dry-packing were easily adapted for use by Pulse. Pulse's customers can achieve significantly higher yields, reduce costly rework and provide improved quality levels to their customers by using existing moisture control procedures for handling Pulse's dry-packed SMT magnetic products

Bibliography:

IPC-SM-786 *Impact of Moisture on Plastic IC Package Cracking*

IPC-SM-786A *Procedures for Characterizing and Handling of Moisture/Reflow Sensitive ICs*

IPC-4202 *Assembly Process Preconditioning for Qualification of Components*

JEDEC Standard JESD22-A112 *Moisture Induced Stress Sensitivity for Plastic Surface Mount Devices*

JEDEC Standard JESD22-A113
Preconditioning of Plastic Surface Mount Devices Prior to Reliability Testing

Ogden, Carl (Brooktree Corporation)
Moisture Induced Cracking of Plastic Encapsulated Integrated Circuit Packages

Lin, R., Blackshear, E., and Serisky, P. (IBM Corporation)
Moisture Induced Package Cracking in Plastic Encapsulated Surface Mount Components During Solder Reflow Process

Kitano, M., Nishimura, A., Kawai, S. (Hitachi, Ltd.)
Analysis of Package Cracking During Reflow Solder Process

Melville, Paul, "Moisture Sensitivity Ratings for SMT Packages", *SMT Magazine* Sept 1994

Morency, Daniel, "PLCC Package Cracking: Is Pre-Assembly Baking the Answer?"
SMT Magazine March 1991

Williams, J. *Desiccant Packaging of Moisture Sensitive Electronic Devices*

McKenna, Robert, "An Overview of Surface Mount Device Packaging Cracking"
SMT Magazine January 1990

Maxwell, John, "Temperature Profiles: The Key to Surface Mount Assembly Process Control"
SMT Magazine July 1990

LaCap, E. and Khan, J. "Baking Eliminates Plastic Package Cracks"
Semiconductor International March 1990

© 1996, Pulse Engineering, Inc.

For More Information :

Corporate	Europe	Asia	Distributor
12220 World Trade Drive	Dunmore Road	Block 3027	
San Diego, CA 92128	Tuam	Ubi Road 1	
Tel: 619 674 8100	County Galway	#03-120	
FAX: 619 674 8262	Ireland	Singapore 408720	
http://www.pulseeng.com	Tel: 353 93 24107	Tel: 65 741 5227	
Quick-Facts: 619 674 9672	FAX: 353 93 24459	FAX: 65 741 3013	

© 1996, Pulse Engineering, Inc.