Moisture and Contamination Considerations for Long Term Storage of End of Life Electronic Components

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Moisture Contamination of Moisture Sensitive Devices (MSD)

The applicable IPC/JEDEC standards addressing moisture sensitive devices are J-STD-020D.1 and J-STD-033B.1 and GEIA-STD-003. The standards deal primarily with moisture intrusion into device packages and the threat of destructive delamination during solder reflow. This failure mechanism has proven to be a significant concern and becomes more critical in the context of RoHS compliant products, long term storage and very fine geometry VLSI components. Many now believe the IPC/JEDEC standards are not stringent or comprehensive enough to account for the case where components are irreplaceable and where systems are mission critical. Of specific concern are the areas of long term reliability, corrosion, the effects of internal interface damage and contamination. These failure modes are not fully addressed in the current IPC/JEDEC standards. Component reliability concerns are especially relevant when dealing with mission critical systems.

Corrosion

Any analysis of the effect of corrosion starts with the chemical principles. Corrosion is a relatively complex reaction due to the presence of catalyst effects. The reaction is complicated by the composition of the unique alloys contained in electronic components. Accepted in theory is that the presence of H2O and O2 is necessary to enable the oxidation reaction and there exists a direct, though not linear, relationship between increased H2O concentration and increased oxidation. A less well understood reaction factor is the presence of salts and other free ions that increase the rate of oxidation, sometimes dramatically. Also important is the ability of accumulated oxide layers, such as Al2O3 and SnO, to prevent access of O2 to the metallic surface thus slowing or preventing the oxidation reaction.

To further complicate the corrosion situation, the surface of critical electronic component packages, for example ball grid arrays, are spherical while research typically focuses on flat surfaces. This makes theoretical estimation of corrosion rates and amounts, as measured in accumulated oxide thickness, difficult to predict. In addition, ball grid array metallurgy has changed significantly in the last several years from Sn63/Pb37 to SAC 305/405 (Sn/3-4%Ag/0.5Cu) to low silver SAC 105 (Sn/0-3.0%AG/0.5Cu). These metallurgical changes have led to an increase in the required solder reflow temperature profile increasing the level of concern for MSD handling and storage.

The Evolution of Components

Electronic components are stored all over the world for use in all manner of electronic products and systems. Many of these components are relatively simple and robust products that can be stored with only passing regard to environmental control and quality processes. These component types, passive, low function active or electromechanical devices, are not the subject of specialized long term storage and care. The storage of simpler components, as long as reasonable ESD control is exercised and severe environments are avoided, does not require specialized procedures. Unfortunately, many electronic system manufacturers treat all components the same when considering long term storage and usage.

The challenge occurs when dealing with high function, leading edge technology semiconductor components. These devices are constructed using silicon and metallization geometries of 45nm (nanometer) going to 32nm in 2011. To put this size into perspective, there are 1 billion nanometers in one meter and you can fit more than 30,000 transistors of 45nm area onto the head of a pin, which measures approximately 1.5 million square nm. Today's highest technology devices contain over 1 billion transistors, all of which must function to specification to make a working component. Additionally, these high technology devices use increasingly lower internal supply voltages (V_{Int} now at 1.2V) and increasingly higher switching frequencies. The effect of lower operating voltage is that it in turn lowers threshold and detection voltages, making the internal circuit elements more susceptible to noise, contamination and reliability issues. Similarly, higher switching frequencies make it increasingly difficult to ensure overall operating conditions.

Today's electronic components rely on principles of physics and science with no manufacturing precedent and little real world data on long term stability and reliability, especially in the harsh environments of military and aerospace systems. These challenges demand that the methods used to document, package, handle, store and use complex semiconductor devices must evolve to keep pace with the underlying technology.

Plastic epoxy packages housing leading edge devices have experienced rapid technology migration, primarily driven by size considerations. Counter intuitively, component assembly evolution and the advent of flip chip technology has resulted in a package that is considerably thinner and less moisture and contamination resistant. Estimates are that 2 billion flip chip components were shipped in 2006 and the volume is projected to grow to over 6 billion by 2010. These devices, specifically plastic ball grid array packages which constitute the bulk of the volume, must be stored and managed carefully if they are to be preserved for long term use. The PBGA package body is composed of either a biphenyl epoxy resin or tri-epoxy resin mixed with fused silica filler in varying amounts. These compounds are not impervious to moisture or other contaminants and do not provide a hermetic seal for the underlying die.

Storage Systems

The optimal storage environment is a perfect vacuum at an ambient temperature of 20C with no source of moisture or other contamination and zero likelihood of environmental control system failure. The balance of the storage discussion results in a tradeoff of cost, handling of the product, integration with manufacturing and risk mitigation. In order of cost, the storage technology solutions are as follows:

1) Secure, monitored cabinet with dry inert gas (N2) ambient

   Advantages

   - Eliminates both O2 and H2O from the corrosion equation making significant reaction improbable
   - May be actively monitored with alerts and operator intervention
   - Prevents moisture intrusion into the package and die cavity minimizing the possibility of internal contamination and catastrophic damage during high temperature solder reflow
   - Removes already accumulated moisture from the device package, resetting floor life
   - Minimizes the possibility of latent reliability concerns due to moisture or other contamination
   - Positive pressure environment limits intrusion from outside environment
   - No device handling required
   - Documented and logged environmental conditions

   Disadvantages

   - Highest variable cost solution, continuous N2 feed required over long storage periods
   - Highest capital investment solution, cabinets and gas feed system
   - Reliable and alarmed N2 source required to ensure uninterrupted service
   - Storage cabinets are not mobile, tied to N2 source and limits business continuity planning
   - Care must be exercised to ensure source purity to prevent introduction of contaminants

2) Secure, monitored dry air active desiccant cabinet maintained to less than 5% relative humidity

   Advantages

   - Eliminates H2O from the corrosion equation making significant reaction improbable
   - May be actively monitored with alerts and operator intervention
   - Prevents moisture intrusion into the package and die cavity minimizing the possibility of internal contamination and catastrophic

damage during high temperature solder reflow
- Removes already accumulated moisture from the device package, resetting floor life
- Minimizes the possibility of latent reliability concerns due to moisture or other contamination
- Minimal variable cost, low power electrical source
- Portable cabinets allow flexibility in business continuity planning
- No external source of contamination
- Documented and logged environmental conditions
- No device handling required

Disadvantages
- Capital investment, cabinets
- External environment must be secured to prevent introduction of contaminants

3) Moisture Barrier Bag (MBB) with passive desiccant replenishment and reseal

Advantages
- Lowest capital investment solution
- Should eliminate O2 from the corrosion equation making significant reaction unlikely
- Material can be moved allowing flexibility in business continuity planning

Disadvantages
- Highest variable cost solution
- Does not removed already accumulated moisture from the device package
- MBB shelf life of 12 months
- Evidence that vacuum sealing increases the likelihood of moisture penetration of bag membrane
- Cannot be actively monitored, desiccant card only
- Cannot be actively logged
- Periodic device handling required
- Baking often required prior to manufacturing, adding cost, disrupting manufacturing flow and introducing mechanical and contamination risk through handling
- No assurance of prevention of moisture intrusion into the device package
- Cannot store for extended periods in factory tape and reel packaging due to failure of carrier to tape adhesion

Conclusions

The most catastrophic storage failure mechanism, delamination during high temperature solder reflow, has been addressed by JEDEC standards that limit exposure time to non-environmentally controlled conditions. Less obvious failure modes such as compromised reliability and shorter operating life have not been addressed by the standards bodies. Additional measures to prevent moisture contamination are required for long term storage of irreplaceable components installed into mission critical systems. Corrosion is an issue however, with environmental control of both O2 and H20 or H20 alone; oxidation is not likely to reach a level that compromises bond integrity.

Storage systems are available to provide secure, moisture and temperature controlled environments to ensure the long term viability of electronic components. The appropriate storage methodology is a function of cost, benefit and risk. The analysis should include consideration of product and end system value and the requirements for end system reliability and survivability. On a cost benefit basis, it is recommended that secure, monitored dry air active desiccant cabinets maintained to less than 5% relative humidity are employed for long term storage of high value obsolete components that are destined for mission critical systems.

References

IPC/JEDEC J-STD- 033A, “Handling, Packaging, Shipping, and Use of Moisture/Reflow Sensitive Surface Mount Devices”, July 2002

IPC/JEDEC J-STD-020D.1, “Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices”, March 2008

GEIA-STD-0003, “Long Term Storage of Electronic Devices”, January 2006

“MSD Control in a High Reliability Production Environment”
APEX Conference 2003
BAE SYSTEMS Information and Electronic Systems Integration Inc.
Information and Electronic Warfare Systems, 65 Spit Brook Rd, Nashua, NH 03061
J. Cambrils, M. Hickey, and D. Tibbets

“New Types of Microelectronic Epoxy Compounds”
Technical Paper
Dexter Electronic Materials, 15051 East Don Julian Road, Industry, California 91746
Horst Rauhut, Ph.D, December 1994

“Moisture Effects on the Soldering of Plastic Encapsulated Devices”
Application Note S2080
Macom Tyco Electronics

“Evaluating Nitrogen Storage as an Alternative to Baking Moisture/Reflow Sensitive Components”
Proceedings of NEPCON WEST 2000; Anaheim, CA, USA
Martin Theriault, *Air Liquide America, Countryside, IL USA*, C. Carsac, P. Blostein
Air Liquide, Versailles, France

“24 months Shelf Life for Moisture Sensitive SC Devices”
PCN# 20040206003
Texas Instruments, 12500 TI Boulevard, MS 8640, Dallas, Texas 75243, April 2004

“Understanding Moisture/Reflow Sensitivity for IC Packages: Achieving Pb-Free Assembly Classification and Handling”
Intel Corp., Jack McCullen, December 2004