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Long-Term Storage for Electronic Solid-State Wafers, Dice, and Devices

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LONG-TERM STORAGE GUIDELINES FOR ELECTRONIC SOLID-STATE WAFERS, DICE, AND DEVICES

Introduction

Age does not adversely affect solid-state electrical performance provided no degradation in materials occurs. This publication provides the industry with the best practices and recommendations for packing and storing solid-state electronics for long-term storage (LTS).

For the purposes of this document, LTS is defined as continuous storage where J-STD-033 does not apply.

LONG-TERM STORAGE GUIDELINES FOR ELECTRONIC SOLID-STATE WAFERS, DICE, AND DEVICES

(From JEDEC Board Ballot JCB-22-36, formulated under the cognizance of the JC-14.3 Subcommittee on Silicon Devices Reliability Qualification and Monitoring.)

1 Scope

This publication examines the LTS requirements of wafers, dice, and packaged solid-state devices. (Note: Packaging may include encapsulation, under-fill, over-mold, or other techniques to attach a die to the next level of assembly.) The user should evaluate and choose the best practices to ensure their product will maintain as-received device integrity and minimize age- and storage-related degradation effects. Major degradation concerns can be driven by moisture-induced corrosion, contamination, electrostatic fields, temperature effects, and outgassing. Please refer to J-STD-033 for non-LTS criteria as well as requirements for moisture sensitivity levels, environmental conditions, dry bag requirements, handling, shipping, and desiccant calculations.

Wafers and dice that are in process or finished may require LTS depending upon program needs. Environmental factors should be evaluated to avoid electrostatic discharge (ESD) damage and to protect the wafer and die bond pads and the device terminal leads against corrosion and damage until any die is packaged or otherwise attached in its next level of assembly. Specific ESD requirements and procedures can be found in ANSI/ESD S20.20, EOS/ESD S8.1, and JESD625 as applicable.

Solid-state devices may be constructed from either organic or ceramic materials. Many organic packaged solid-state devices are designed to attach the semiconductor die to copper die bond pads or heat spreaders or stiffeners. These packages utilize organic resins and other carbon-based materials which can absorb and retain moisture, leading to failure mechanisms such as delamination, corrosion, and warpage. Ceramic solid-state devices are constructed from inorganic materials such as alumina or glass frit. Ceramic devices can develop corrosion from moisture exposure. Ceramic devices can be damaged from handling.

Effective use of this publication is intended to prevent environmental damage to and maintain reliability of wafers, dice and unassembled solid-state devices during LTS. Product destined for LTS should be free from any initial storage concerns, including contamination from process chemicals, fluxes, handling damage, etc. LTS product should be inspected prior to use to ensure no detrimental effects. Metallic whiskers (such as tin, silver, copper) could develop depending upon moisture and temperature environmental conditions. This document does not relieve the supplier of the responsibility to meet internal or customer specified requirements or qualification programs.

2 Terms and Definitions

critical moisture limit: The maximum safe equilibrium moisture content for a specific encapsulated device at reflow assembly or rework.

interlevel dielectric (ILD): The dielectric material used to electrically separate closely spaced interconnect lines arranged in several levels (multilevel metallization) in an advanced integrated circuit

long-term storage (LTS) : Uninterrupted storage where the conditions and requirements of J-STD-033 do not otherwise apply; e.g., safe storage, shelf life, floor life.

NOTE Allowable storage durations will vary by form factor (e.g., packing materials, shape) and storage conditions. In general, long-term storage is greater than one year.

LTS packaged hardware: The wafers, dice, or encapsulated devices that have additional packaging for storage to protect from moisture and mechanical impact and for ease of identification and handling.

LTS storeroom: An area containing wafers, dice, or packaged devices that have additional packaging for storage to protect from moisture or from mechanical impact or for ease of identification or handling.

moisture-sensitive device (MSD): Any device that exhibits moisture absorption or moisture retention and whose quality or reliability is affected by moisture.

next-level assembly: The attachment of a die or packaged device to the next level of assembly packaging.

printed circuit board (PCB): A substrate used to mechanically support and electrically connect electronic components using conductive pathways or signal traces by printing or etching tracks of a conductor such as copper on one or both sides of an insulating substrate.

NOTE A PCB is also called a printed wiring board (PWB) or etched wiring board.

under-bump metallization (UBM): A patterned, thin-film stack of material that provides 1) an electrical connection from the silicon die to a solder bump; 2) a barrier function to limit unwanted diffusion from the bump to the silicon die; and 3) a mechanical interconnection of the solder bump to the die through adhesion to the die passivation and attachment to a solder bump pad.

under-bump metallurgy (UBM): The metal layers located between the solder bump and the die.

3 References and Other Useful Resources

3.1 IPC[1] / JEDEC[2]

IPC-T-50, *Terms and Definitions for Interconnecting and Packaging Electronic Circuits.*

JESD88, *Dictionary of Terms for Solid State Technology*.

IPC/JEDEC J-STD-033, *Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices.*

JESD201, *Environmental Acceptance Requirements for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes.*

JESD625, *Requirements for Handling Electrostatic Discharge Sensitive (ESD) Devices*.

IPC/JEDEC J-STD-020, *Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices*.

IPC-1601, *Printed Board Handling and Storage Guidelines*.

JESD22-B118, *Semiconductor Wafer and Die Backside External Visual Inspection.*

JESD22-B116, *Wire Bond Shear Test Method*.

J-STD-002, *Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires.*

JEP122, *Failure Mechanisms and Models for Semiconductor Devices*.

3.2 ANSI[3]

ANSI/ESD S20.20, *Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)*.

ANSI/ESD STM11.11 *Surface Resistance Measurement of Static Dissipative Planar Materials.*

ANSI/ESD STM11.12 *Volume Resistance Measurement of Static Dissipative Planar Materials.*

ANSI/ESD STM11.13 *Two-Point Resistance Measurement of Static Dissipative Materials*

3.3 Electrostatic Discharge Association (ESD)[4]

EOS/ESD S8.1, *Protection of Electrostatic Discharge Susceptible Items - Symbols - ESD Awareness*.

3.4 Military Standards[5]

MIL-PRF-81705, *Performance Specification Barrier Materials, Flexible, Electrostatic Protective*.

MIL-PRF-131H, *Barrier Materials*.

3.5 ISO[6]

ISO 14644, *Cleanrooms and Associated Controlled Environments*.

3.6 ASTM[7]

ASTM D3330, *Standard Test Method for Peel Adhesion of Pressure-Sensitive Tape*.

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1. www.ipc.org
2. www.jedec.org
3. www.ansi.org
4. www.esda.org
5. www.dscc.dla.mil/Programs/MilSpec
6. www.iso.org
7. www.astm.org

4 LTS Control

The following recommendations are best practices when storing wafers, dice, or solid-state devices. This guideline does not preclude the use of specialized tools or equipment or alternative storage practices (e.g., use of moisture regulators, electrostatic discharge protection systems, etc.) for LTS control. Alternative practices should be evaluated and documented to ensure conformance to product requirements and LTS criteria.

4.1 Materials

Packing materials that deteriorate with age should not be used since outgassing of chemicals and decomposition products could contaminate the product. Use of specific materials for LTS should be identified and utilized (e.g., closed-cell foams with nitrogen filling).

4.1.1 Moisture Barrier Bag (MBB)

Refer to J-STD-033. Utilization of MBBs for LTS is not limited to MSD hardware. The use of MBBs is good practice for device protection during LTS. Dry packing has a finite effective life for moisture protection due to the limited absorption capability of the desiccant and moisture penetration through the packing material.

4.1.2 Desiccant

Refer to J-STD-033.

NOTE If a storage condition other than 38 °C /90% RH is utilized, recalculation of the WVTR is recommended. The driving force for moisture to penetrate the bag is the water vapor pressure differential between inside and outside the bag. Consider the inside of the MBB at 0 mbar. The mbar outside the bag is dependent on temperature and humidity. The WVTR is a linear function of the water vapor pressure differential; therefore recalculate the effective WVTR.

EXAMPLE:

The water vapor pressure at 38 °C/90 % RH is 60 mbar; at 25 °C / 80% RH, it is 25 mbar. If the WVTR is 0.002 g (100sqinch * day) at 38°C /90% RH, it will be 0.002/60*25 = 0.0008 g (100sqinch*day) at storage condition 25 °C / 80% RH.

4.1.3 Humidity Indicator Card (HIC)

Refer to J-STD-033. Assurance should be made that there is no degradation in HIC performance during LTS.

4.1.4 Dry Nitrogen Atmosphere

Nitrogen environments of 5% RH or less shall be in accordance with MIL-PRF-27401, Type 1 Gas, Grade C (99.995%). The use of other atmospheric conditions should be evaluated to ensure performance to LTS requirements.

4.1 Materials (cont'd)

4.1.5 High purity dry air Atmosphere

Maximum 5% RH, 0.04% CO_2, 0.001% Cl_2, 0.001% S, 0.001% P. The use of other atmospheric conditions should be evaluated to ensure performance to LTS requirements.

4.1.6 Storage Containers

Material used in contact with or in close proximity to the wafer, die, or device surface must preserve product integrity. The container should provide protection from contamination, abrasion, and outgassing. When ESD concerns are warranted, proper materials and procedures should be used.

4.1.7 Foams, Packing Material and Protective Cushioning

If used, material for LTS should not contaminate contents. Nitrogen-filled, closed cell foam is an example of a suitable material for LTS. If using a carbon-filled variant of this type of foam, take care to ensure that the carbon is fixed in the material and cannot shed particles during LTS. The packing material should be able to meet the LTS life. In particular, any packing item that could give rise to chemical or particulate contamination by long-term degradation should be avoided. Paper used to separate product (e.g., Tyvek ™, etc.) should be contaminant free and meet application ESD requirements. Materials coated with films to reduce static charge (i.e., ESD-coated) should be evaluated for outgassing concerns. Barrier materials as defined by MIL-PRF-131 should be tested to confirm LTS performance is acceptable.

4.2 General Storage Environment

The storage environment for LTS packaged products should be controlled to minimize vibrations and product handling. Temperature control is important to provide protection from material decomposition and warpage mechanisms. It is important to prevent rapid temperature changes that could cause moisture condensation based upon the saturated vapor pressure of water in the container or thermal shock failure mechanisms. Temperature ramp rates should be controlled so the product maintains a thermal equilibrium to prevent thermal shock or moisture condensation. Humidity control is important as MBB integrity is directly related to the humidity exposure. Maximum storage time depending upon HIC response can be calculated using the Water Vapor Transmission Rate (WVTR) as defined in J-STD-020.

General warehouse temperature and humidity storage environments should be evaluated for wafer, die, and device LTS concerns. Typical warehouse temperatures are less than 40 °C. Typical warehouse humidity is less than 90% RH. Consideration should be made with the storage materials to reduce the likelihood of outgassing. Outgassing can be related to temperature exposure of the LTS material (including foams, trays, gaskets, insulators, topical antistats, etc.), thus evaluation of maximum storage temperatures should be performed. Product exposed to the environment outside of LTS packaging should follow J-STD-033 for storage. Typical temperature ranges for wafers, dice, and modules not in LTS are 20 °C to 35 °C (68 °F to 95 °F). Typical humidity is 40% to 60% RH. Wafers and die removed from LTS for processing should also follow the requirements found in ISO 14644 where applicable.

Any temperature or humidity excursion outside these limits should be recorded and logged. Non-conforming conditions should be identified, evaluated, and modified by appropriate corrective actions.

4.3 LTS Methods

LTS is designed to prevent product degradation due to oxygen, moisture, and/or outgassing mechanisms. The LTS protection method employed depends upon the mechanism of concern. When considering multiple mechanisms, one may need a combination of prevention methods.

4.3.1 Dry Cabinet Storage

Product stored in a dry cabinet should be maintained at 7-10% RH for MSL 2 or 3 and maximum 5% RH for MSL 4 or 5 unless device application requirements or other specification indicate a different minimum RH value. Refer to J-STD-020 for moisture classification levels, floor life requirements, and reflow limitations prior to use. Atmosphere should be high purity dry air, dry nitrogen, or any other dry inert gas atmosphere as required by the supplier. The pressure should be sufficiently high to prevent the ingress of external atmosphere contaminates.

4.3.1.1 Humidity Controlled Storage

The cabinets should be capable of recovering to their stated humidity rating within one hour from routine excursions such as a door being opened and closed. To limit possible moisture exposure from ambient atmosphere, the suggested time limit for dry cabinet open door is 10 minutes cumulative per 8 hours for a total of 30 minutes cumulative per 24 hour period. The suggested maximum time the door may be open in any period is 8 minutes to allow the humidity to recover to below 25% RH.

4.3.1.2 Oxygen (O_2) Controlled Storage

The recommended atmosphere is dry nitrogen or any other dry inert gas atmosphere. The pressure should be sufficiently high to prevent the ingress of external atmosphere contaminants. For oxygen exposure, an inline monitor or other detection methods should be employed.

4.3.1.3 Outgassing-Controlled Storage

Atmosphere shall be high purity dry air, dry nitrogen, or any other dry inert gas atmosphere as required by the supplier. The pressure should be sufficiently high to prevent the ingress of external atmosphere contaminants. The cabinet should have an atmospheric exchange rate sufficient to prevent internal atmospheric contamination.

4.3.2 Vacuum MBB Storage

Vacuum MBB is commonly used for shipping and storing wafers, dice, and devices. The use of vacuum MBB for LTS requires confirmation that the product is maintained at an acceptable moisture level. The most common method to identify moisture exposure in the MBB is to include a HIC. The use of HICs in MBBs for wafers and/or dice storage is optional due to potential contamination concerns. Users should determine if HIC use with wafers and/or dice are acceptable. Care should be exercised on the force of vacuum applied to ensure product and package integrity. Vacuum force can create damage on packing materials; as such, the appropriate vacuum force should be identified and ensured. A visual check should be performed to verify the MBB sealed conditions prior to use.

4.3.2 Vacuum MBB Storage (cont'd)

4.3.2.1 Humidity Controlled Storage

The use of vacuum MBB for LTS requires confirmation that the HIC displays acceptable moisture level exposure prior to using contents.

4.3.2.2 Oxygen (O_2) Controlled Storage

Flush the MBB with dry nitrogen or any other dry inert gas to ensure ambient atmosphere is totally removed. Vacuum is applied immediately after the flush. An oxygen sensor or other detection methods should be employed to ensure compliance is met.

4.3.2.3 Outgassing Controlled Storage

Flush the MBB with nitrogen, dry air, or any other dry inert gas to ensure ambient atmosphere is totally removed. Vacuum is applied immediately after the flush.

4.3.3 Nitrogen (N_2) Flush or Positive-Pressure MBB Storage

When utilizing an MBB for LTS, one should evaluate if a positive pressure system is required. In this system the MBB initially undergoes a vacuum followed by backfill with dry nitrogen, dry air, or any other dry inert gas. The use of nitrogen flush prior to sealing the MBB creates an inert atmosphere that enhances product storage. Positive pressure sealing provides easy confirmation that the MBB is intact by observing bag inflation. However, one should ensure protection from bag punctures and verification that environmental influences (such as air transport) do not affect the integrity of the inflated bag.

4.3.3.1 Humidity Controlled Storage

The use of positive pressure MBB for LTS requires confirmation that the HIC displays acceptable moisture level exposure prior to using contents.

4.3.3.2 Oxygen (O_2) Controlled Storage

The MBB initially undergoes a vacuum followed by back-fill with dry nitrogen or any other dry inert gas. An oxygen sensor or other detection methods should be employed to ensure compliance is met.

4.3.3.3 Outgassing Controlled Storage

The MBB initially undergoes a vacuum followed by back-fill with dry nitrogen, dry air, or any other dry inert gas.

4.4 LTS Double Containment Redundancy

Optional redundancy in LTS capability may be possible by using double containment. Examples of double containment are placing the original MBB within another MBB, or by storing the original MBB within a LTS cabinet containing appropriate environmental conditions.

4.5 Storage Details

The verification testing details can be found in Clauses 5 and 6 under the appropriate sections.

4.5.1 Wafer

Exposure Concern	LTS Packaging Method	LTS Verification	Environment/ Specifications	Storage Time Limitation	Preconditions	Contents Verification Testing
Moisture	MBB, HIC when acceptable	HIC (when acceptable); MBB seal integrity	See 4.3.2 and 4.3.3	Based on HIC results where applicable; verification testing results	NA	Inspection[1]; Bondability (Wire)[2]; Solderability (C4 Solder)[3]
Moisture	Dry Cabinet	Atmosphere Flow Meter	See 4.3.1	verification testing results	NA	As above
Oxygen	N_2 or Inert Gas Dry Cabinet	Gas Flow Meter; ppm O_2 detection; O_2 sensors;	See 4.3.1	verification testing results	NA	As above
Oxygen	MBB without air	O_2 sensors; MBB seal integrity	See 4.3.2 and 4.3.3	verification testing results	NA	As above
Outgassing	N_2 , Inert Gas, or Air Dry Cabinet	Gas Flow Meter	See 4.3.1	verification testing results	NA	As above
Outgassing	MBB	MBB seal integrity	See 4.3.2	NA	NA	As above

NOTE 1 Such as JESD22-B118 for backside or other applicable inspections
NOTE 2 Such as JESD22-B116 or other applicable testing
NOTE 3 Such as J-STD-002 or other applicable testing

4.5 Storage Details (cont'd)

4.5.2 Die

Exposure Concern	LTS Packaging Method	LTS Verification	Environment/ Specifications	Storage Time Limitation	Preconditions	Contents Verification Testing
Moisture	MBB; HIC when acceptable; NOTE 2	HIC (when acceptable); MBB seal integrity	See 4.3.2 and 4.3.3	Based on HIC results where applicable; verification testing results	NA	Inspection[1]; Bondability (Wire)[2]; Solderability (C4 Solder)[3]; Underfill / Adhesive Integrity[4]
Moisture	Dry Cabinet	Atmosphere Flow Meter	See 4.3.1	verification testing results	NA	As above
Oxygen	N_2 or Inert Gas Dry Cabinet	Gas Flow Meter; ppm O_2 detection; O_2 sensors;	See 4.3.1	verification testing results	NA	Inspection[1]; Bondability (Wire)[2]; Solderability (C4 Solder)[3]
Oxygen	MBB without air	O_2 sensors; MBB seal integrity	See 4.3.2 and 4.3.3	verification testing results	NA	As above
Outgassing	N_2 , Inert Gas, or Air Dry Cabinet	Gas Flow Meter	See 4.3.1	verification testing results	NA	Inspection[1]; Bondability (Wire)[2]; Solderability (C4 Solder)[3]; Underfill / Adhesive Integrity[4]
Outgassing	MBB	MBB seal integrity	See 4.3.2 and 4.3.3	verification testing results	NA	As above

NOTE 1 Such as JESD22-B118 (for backside inspection) or other applicable inspections
NOTE 2 Such as JESD22-B116 or other applicable testing
NOTE 3 Such as J-STD-002 or other applicable testing
NOTE 4 Verification of underfill encapsulate or die attach adhesive integrity includes examination for delamination, voiding, poor fillets, etc.
NOTE 5 The use of dessicant may be required for polymer based ILD or passivation layers; this should be evaluated for the product and defined by the product requirements.

4.5 Storage Details (cont'd)

4.5.3 Device

Exposure Concern	LTS Packaging Method	LTS Verification	Environment/ Specifications	Storage Time Limitation	Preconditions	Contents Verification Testing
Moisture	MBB with desiccant, HIC	HIC; MBB seal integrity	See 4.3.2 and 4.3.3	Based on HIC results; verification testing results	Bake out if required per J-STD-033	Inspection[1]; Solderability (solder leads)[2]
Moisture	Dry Cabinet	Atmosphere Flow Meter	See 4.3.1	verification testing results	Bake out if required per J-STD-033	As above
Oxygen	N_2 or Inert Gas Dry Cabinet	Gas Flow Meter; ppm O_2 detection; O_2 sensors;	See 4.3.1	verification testing results	NA	As above
Oxygen	MBB	O_2 sensors; MBB seal integrity	See 4.3.2 and 4.3.3	verification testing results	NA	As above
Outgassing	N_2 , Inert Gas, or Air Dry Cabinet	Gas Flow Meter	See 4.3.1	verification testing results	NA	As above
Outgassing	MBB	MBB seal integrity	See 4.3.2 and 4.3.3	verification testing results	NA	As above

NOTE 1 Such as JESD22-B118 (for backside inspection) or other applicable inspections
NOTE 2 Such as J-STD-002 or other applicable testing

4.6 Storage Considerations for Devices after Card (or Other) Attachment

Once a device is attached (i.e., no longer a standalone entity), recommended storage conditions are still not unlimited. The primary owner for higher level assemblies (assembled cards, systems, etc.) into which a standalone device has been integrated by some attachment process should deploy storage controls which comprehend continuing risks to all components of those higher-level assemblies. In the absence of a comprehensive control strategy for higher level assemblies, the same storage protections recommended for standalone devices will also protect those devices after integration into higher-level assemblies.

NOTE Other storage considerations may exist for the non-device constituents of the higher-level assembly also. For additional information on printed board assemblies, please see IPC-1601 Printed Board Handling and Storage Guidelines.

4.7 Handling

If any component is removed from LTS and is exposed to the ambient atmosphere, it shall be handled in accordance with J-STD-033 for moisture sensitivity, ISO 14644 for wafers and die in controlled environments, and ANSI/ESD S20.20/ EOS/ESD S8.1, and/or JESD625 for ESD if required. Unless otherwise allowed by the manufacturer, the environmental conditions shall be maintained at a temperature below 30 °C (86 °F) and humidity below 60% RH. Unpackaged solid-state devices shall not be removed from their sealed packaging unless the facility has proper cleanliness and environmental controls that meet the manufacturer’s requirements.

During storage, sufficient protection should be provided to guard against damaging movement or vibrations. Orientation may be important for both product usage as well as limiting mechanical damage from shock and vibration. Containers and shelving may require anti-vibration or anti-resonance mounting. Packing material should be designed to offer some degree of protection against handling damage.

4.8 Inspection

Product shall be inspected and visual observations verified by using appropriate magnification as defined by application requirements and documented in applicable drawings and/or specifications. Additional lighting may be required to enhance the inspection. Unusual observations should be evaluated to verify acceptance to Clause 5 failure concerns, handling damage, contamination, or any other obvious damage.

4.9 Inventory Control Process

A tracking system can be established to ensure that inventory traceability is maintained where required. Care should be taken to ensure that any information from labels on the primary packaging are kept with the product batch. Some programmable devices may contain lot traceability in electronic form. Handling and storage processing should ensure that the electronic data is not compromised.

4.10 Transportation

Product movement during LTS requires evaluation that there is no damage. If product is removed from LTS and exposed to the environment during transportation, then J-STD-033 applies.

4.11 Lead Finishes

Product lead finishes can be a factor in LTS. Refer to lead finish guidelines in JESD201.

5 LTS Concerns

LTS time may be impacted by improper storage conditions. Potential causes of storage concern such as environmental conditions (including temperature, humidity, moisture, pressure, atmospheric gases, electrostatic field charge, applied physical forces, etc.), handling (shock, vibration, impacts, etc.), contamination, material shelf life, or other applied stress factors could have an effect on overall LTS life. Degradation mechanisms that are induced with moisture may happen if the integrity of the dry storage (cabinet, MBB) is violated. Verification of moisture exposure includes, but is not limited to, examination of the HIC for any change in color, chamber humidity monitoring, and the use of recording devices that indicates moisture exposure. Different materials can absorb moisture at different rates and must be evaluated based upon exposure time. For other degradation mechanisms that require oxygen, radiation, electrical exposure, or mechanical impact, the LTS environment should be evaluated to prevent contributing towards failure concerns.

NOTE Packing materials used in LTS should be evaluated for moisture absorption and release. The packing requirements of J-STD-033 should be followed for LTS unless otherwise indicated in this publication.

5.1 Solderability

Device surfaces that will be soldered to another surface using reflow operations should join successfully. Solderability determines whether the surfaces intended to be joined metallurgically can perform as expected. Failure to form a complete metallurgical joint can result in conditions known as non wets or dewets; oxides typically contribute to solderability degradation. LTS factors that can impact the ability for a part to form a good metallurgical joint include humidity, oxygen exposure, cleanliness, foreign material, and contamination.

5.2 Popcorning

Moisture content within a material when heated rapidly results in expansion of the moisture in form of vapor. This vapor occupies greater space then the moisture from which it was derived. If this vapor is not allowed to dissipate then the materials within which it is contained will increase in size and exceed the strength or ability of the material to contain the vapor. Subsequently an electronic device that was manufactured correctly (i.e., all materials were properly adhered) may then develop a loss of adhesion. This may lead to interface delamination, package blistering, cracking, and bubbling.

5.3 Delamination

Delamination can occur when moisture accumulates in the materials, voids or at the interface between layers. Subsequent exposure to cycling or thermal processing can cause a separation of materials. Die with organic passivation, organic substrates, and PWBs tend to absorb moisture which could subsequently outgas during high-temperature processing. The primary failure mode is interfacial disbanding and cohesive separation.

5.4 Corrosion

Corrosion is a chemical reaction that results in the oxidation and/or structural decomposition of metals. Metal migration is also a form of corrosion. Moisture enhances corrosion mechanisms; contaminants (including fluorine and chlorine) may be hydrated with atmospheric moisture or pollutants during shipment, handling and ambient storage and act as corrosion catalyst. Eliminating the moisture is key to inhibiting corrosion. Corrosion can lead to opens, shorts, dendrites, and discoloration.

5.5 Wire Bondability

Wire bondability can be impacted by oxides and/or contamination. Proper storage procedures are required to prevent moisture contamination from occurring.

5.6 Staining

Moisture-induced stains can be created during LTS on surfaces where the dry conditions have been compromised. Contaminants including fluorine and chlorine have been shown to enhance the creation of such stains. Stains may lead to aesthetic concerns as well as affect visual marking legibility.

5.7 Adhesives

5.7.1 Die on Wafer Film Frames

Die on wafer film frames may be subject to problems of removal from adhesives which tend to change adhesive strength over time. In cases of long storage, a residue of the adhesive may remain on the backside of the die. This could be a reliability concern for die in which the backside is used for a thermal and/or electrical connection. An adhesive residue on the backside of the die can prevent the formation of a complete solder joint or contaminate some thermal interface materials, which in-turn could degrade part or all of the thermal function and/or electrical connection.

5.7.2 Devices and Dice Embossed or Punched Tape Storage

Devices and die stored in embossed or punched tape may be subject to problems in removing the cover tape due to changes in adhesive strength over time. Industry tape adhesion testing (ASTM D 3330 or similar) can be used to evaluate changes in adhesive strength. Any LTS methodology should take into account length of storage and temperature ranges to avoid inducing issues.

5.8 Handling Damage

Defects caused by handling, transportation, vibration, mechanical impact, or other mechanical influences may affect susceptible regions of the wafer, die, or device and should be considered when designing long-term storage solutions. Damage to bagged desiccant must be avoided to eliminate loose desiccant concerns which may cause particle dispersion. Tears in the MBB can allow the external environment to compromise the LTS integrity. Shifting of trays or product can cause scuffs and debris contamination.

5.9 Electrical Effects

Conductive or electro-static (ES) dissipative materials should be used when required for ESD protection. ESD may be caused by using inappropriate packing materials, relative humidity (RH) extremes or other environmental contaminants, or proximity to ES field sources. This may lead to p-n junction damage, oxide breakdown/puncturing, or other sensitive parameter effects.

Coated-type ES dissipative storage media can degrade over time (e.g., by removal of surface-treatments, by wear or other mechanical means, by exposure to some environmental factors).See clause 6 for recommendations on resistance testing.

5.10 High Energy Ionizing Radiation Damage

Exposure to ionizing radiation (e.g., as from x-rays or other high energy radiation sources) must be quantified to understand potential damage. Product may have sensitivity to the ionizing charge effects. Some die types, such as analog devices, may be particularly sensitive. Care should be taken to ensure protection from ionizing radiation sources for those products that are sensitive.

5.11 Storage Temperature Risks to Semiconductor Devices

Exposure to heat over time can accelerate some semiconductor failure mechanisms, including stress voiding in metallization and data loss in some non-volatile memory cell types that have been written to a desired state prior to storage. Refer to JEP122 for further detail on such mechanisms.

6 Evaluation of LTS

For LTS of products, it is possible to evaluate the adequacy of the storage process and the condition of the stored product by sample testing. If approved by both customer and supplier, surrogate hardware can be used to evaluate similar type components in LTS. Representative samples of the product may be removed from LTS on a regular schedule appropriate to the device and storage protocol. The sample should be checked for any signs of damage or deterioration and if necessary assembled to check for subsequent reliability and performance.

The type of LTS testing to be performed is dependent upon the defect mode under investigation as well as the product requirements. The following evaluations are examples of LTS testing methodology that can be used to understand the LTS operation; use of these or any other methods and establishing the pass/fail criteria must be based on the LTS objectives.

1) Weight Gain Measurement - weigh components immediately upon removal from the MBB. Compared with weights after dry bake for 24 hours at 125 °C. The evaluation is used to determine the amount of moisture the product absorbed during the LTS period.
2) Assembly Integrity Evaluation – Remove components from MBB and immediately perform 3X leadfree reflow per J-STD-020 and conduct C-Mode Scanning Acoustic Microscope (C-SAM) to examine for delamination or product physical changes.
3) Cross-sectioning of Lead frame Packages after LTS - Determine the intermetallic growth between base metal and plated material. Compare with recent manufactured parts.
4) Resistance testing for integrity of ESD protection by storage materials – Use ANSI/ESD STM11.11, 11.12, and or 11.13 as applicable.

When testing shippable product, care should be taken to avoid unnecessary disturbance of stored components. A balance should be sought between the desire for periodic evaluation and the need to maintain an undisturbed storage environment.

The following guidelines are provided to address possible defect modes:

6.1 Noble Metal Finishes

No failure mechanisms have been identified that would compromise the reliability of plastic encapsulated solid-state devices with lead finishes containing Au or Pd due to storage for extended periods of time in a warehouse environment (<40 °C and <90% RH).

6.2 Matte Tin and Other Finishes

Assuming proper MSL protection for the term of storage, lead finishes not containing Au or Pd may require tests such as solderability or such as for tin whisker risks as per JESD201 on aged units to confirm long-term storage integrity.

6.3 Solder Ball and Solder Bump

Assuming proper MSL protection for the term of storage and that the solder balls or bumps are fully reflowed, no failure mechanisms have been identified that compromise the reliability of solder balled or bumped BGA packages stored for extended periods of time in a warehouse environment (<40 °C and <90% RH). However, if the solder balls or bumps are not reflowed but are attached with an adhesive or a solder paste that has a lower melting point, the solder balls or bumps must be examined for oxide growth that could affect adhesion or solderability. Surface analysis of the balls/bumps and solderability testing on aged units may be required to confirm acceptance for attach of the next level of assembly after long-term storage.

Annex A Report form - External Visual

This form or an equivalent form may be used to report the results of external visual inspection.

Part Number	
Description	
Lot Number	
Supplier	
Applicable Drawing Number	
Applicable Specification Number	
Quantity inspected	
Quantity good	
Date	
Inspector	
Comments - failed condition	

Annex A Report form - External Visual (cont'd)

A.1 Inspection Report

Inspected:		**Yes**	**No**	**N/A**
Defects List	**A/U***	**Comments**		
Other:				

Annex B Revision change summary

B.1 Differences between JEP160A and original JEP160:

Clause	Change
3.1	Deleted JEP113 and added JESD22-B118 and -B116, J-STD-002, JEP122
3.2	Added ANSI/ESD STM11.11, 11.12, and 11.13
4.5	Note 3 in each table changed from JESD22-B102 to J-STD-002
4.7	Revised name to ANSI/ESD S20.20
5.9	Changed “too low relative humidity” to “ (RH) extremes or other environmental contaminants” Added paragraph “Coated-type ES dissipative storage media can degrade…”
6	Added “4) Resistance testing for integrity of ESD protection….”
6.1 & 6.3	Removed reference to JEP113

Standard Improvement Form **JEDEC JEP160A**

The purpose of this form is to provide the Technical Committees of JEDEC with input from the industry regarding usage of the subject standard. Individuals or companies are invited to submit comments to JEDEC. All comments will be collected and dispersed to the appropriate committee(s).

If you can provide input, please complete this form and return to:

JEDEC
Attn: Publications Department
3103 North 10th Street Suite 240S
Arlington, VA 22201

Fax: 703.907.7583

1. I recommend changes to the following:
   - [ ] Requirement, clause number ________
   - [ ] Test method number ________ Clause number ________

   The referenced clause number has proven to be:
   - [ ] Unclear [ ] Too Rigid [ ] In Error
   - [ ] Other ________

2. Recommendations for correction:

____
____
____
____

3. Other suggestions for document improvement:

____
____
____
____

Submitted by

Name: ________ Phone: ________

Company: ________ E-mail: ________

Address: ________

City/State/Zip: ________ Date: ________

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