

# Obsolescence Management & the Impact on Reliability

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## Abstract

Component obsolescence management is a strategic practice that also mitigates the risk of counterfeit parts. Left unchecked, obsolescence issues increase support, development and production costs. So, planning ahead is critical. For companies that do proactively manage component availability and obsolescence, the effect of long-term storage on manufacturability and reliability is the area of major concern. Many issues can arise depending on the component technology and storage environment. Reliability concerns to consider include solderability, stress driven diffusive voiding, moisture, Kirkendall voiding, intermetallics/oxidation and tin whiskering.

When component obsolescence isn't planned for, the secondary market is often the supply chain of last recourse. While it is possible to get high quality, genuine parts, it is also possible to get nonconforming, reworked, or counterfeit components. And, it is increasingly difficult to differentiate genuine parts from their counterfeit equivalents. Historically, the secondary market provided a mechanism for finding parts in short supply or at reduced cost. Today, high-reliability system manufacturers are less willing to risk contamination of their supply chain with potentially substandard parts in order to save a few dollars on the cost of a part.

This paper will cover obsolescence management strategies, relevant industry standards, use of managed supply programs (MSP) and contract pooled options, plus long term storage recommendations and practices.

**Keywords:** obsolescence, risk, reliability

## I. INTRODUCTION

Component obsolescence management is a critical practice that allows businesses to anticipate & plan for supplier disruption, end of life parts, aging technologies, and long life programs. Companies that don't prepare for obsolescence are extremely vulnerable to counterfeits and quality and reliability challenges. For companies that do proactively manage component availability and obsolescence, the effect of long-term storage is the area of greatest concern. Depending on the technology and storage environment, failure mechanisms to consider include solderability, intermetallics/oxidation, stress driven diffusive voiding, moisture, Kirkendall voiding, and tin whiskering. Of all of these, solderability and wettability remains the number one challenge.

In order to create a comprehensive component obsolescence program, it is helpful to start with a review of some of the available standards. The most relevant industry standard for storage reliability is the "ANSI-GEIA-STD-0003 Procedures for Long Term Storage of Electronics". This document was created to provide an industry standard for Long Term Storage (LTS) of electronic devices by drawing from the best long term storage practices currently known. For the purposes of the standard, LTS is defined as any device storage for more than 12 months. However, component storage times are generally much longer. While the standard focuses on unpackaged semiconductors and packaged electronic devices,

it may be applied to other components as well. In the standard, Electronic Devices are defined as any packaged electrical, electronic, electro-mechanical (EEE) item, or assemblies using these items. Unpackaged semiconductors are semiconductor wafer or dice. The standard is intended to ensure that adequate reliability is achievable for devices after long term storage. It does not replace the need to request data from suppliers or to generate internal data that demonstrates successful storage life for the duration desired by the user. The standard discusses the appropriate storage conditions, containers, and documentation needed for the three levels defined within. Sub-reference standards within the ANSI/GEIA-003 include:

- MIL-PRF-27401 Propellant Pressurizing Agent, Nitrogen
- MIL-PRF-81705 Barrier Materials, Flexible, Electrostatic Protective, Heat-Sealable
- JESD 625 Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices
- JESD-033 Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices

The MIL-HDBK-338B Electronic Reliability Design Handbook provides another viewpoint on the issue. For many reliability predictions, if the equipment is off or non-functioning, the failure rate is assumed to be insignificant, perhaps even zero. Field evidence and experimental data, however, show that assumption to be false. Many types of

components can experience failures even when no electrical stresses are applied since other stresses are still present. Some of these other stresses include temperature, acceleration, shock, corrosive gases, and humidity. Variations in all of these can be experienced in a long term storage environment. For some components, the storage failure rate can actually be worse than the expected operating failure rate and at lower stress levels.

Companies may choose to create their own obsolescence and long term storage program or they may elect to choose a provider for the service. Regardless of who manages the program, the critical elements to consider are identical. Asset security is vital to protect against loss and theft and simply to keep track of components over the long term. Any component going into storage must be subjected to some form of incoming inspection process which confirms both authenticity and conformance to quality requirements. Documentation on product genealogy (origin) and condition is also required with data for manufacture, transportation, and any prior short term storage included. Any environmental data, lot codes, and date codes should also be tracked. The same component from different lots and date codes may behave very differently after storage. The case study detailed later in this paper will clearly illustrate this point. The storage environment should be maintained as per the ANSI/GEIA 003 Standards with active desiccant storage at less than 5% relative humidity or dry nitrogen storage per MIL-PRF-27401.

Long term data management systems must also be capable of maintaining and managing individual date and lot codes over time. Parts may be pulled and used at varying times in partial or full lots. And, some testing during storage must be performed. This “continuing” data needs to be captured and updated to maintain the integrity of the information. Finally, the obsolescence program must indeed assure the parts supply actually needed over the duration needed. Maintaining data appropriately will help give insight as to how well the system is working. Data integrity will also help give an early warning if supplies are depleting or degrading faster than anticipated. This provides the procurement organization more time to respond appropriately and avoid having to purchase from suppliers outside approved distribution channels.

Figure 1 shows the complexity of capturing product genealogy. In this example, a semiconductor was fabricated and assembled in Asia, tested in Europe, and sent to a US distributor prior to being sold to the end user.

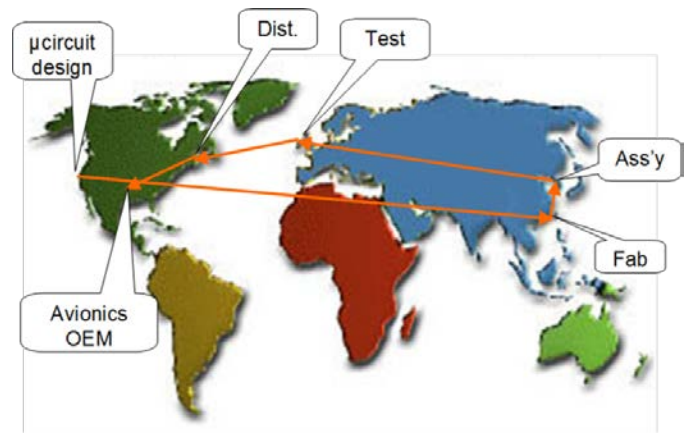


Figure 1 Product Genealogy, Courtesy Lloyd Condra, Boeing

## II. MANAGED SUPPLY PROGRAMS (MSPs)

For companies that don't want to manage the logistics of a component obsolescence program, there are businesses that offer managed supply programs (MSPs). Some of services provided include purchasing and holding of obsolete components, long term storage, component contract financing, stock pooling and optional stock holdings, product quality inspection and management, and contract terms up to 20 years.

Contract or stock pooling options involve paying a percentage of the parts cost over some defined time interval from the manufacturer or MSP provider. Less purchase investment is required by avoiding the upfront cost of completely purchasing all the parts needed. The percentage payment ensures that the parts are stocked and available when needed. This option also results in less inventory cost to a business and reduced risk of losing or damaging stocked parts. Storage space is not needed and the warranty period doesn't begin until a part is purchased from the pool. With purchased parts, the warranty period starts on the actual date of purchase. This can be a significant advantage if problems arise.

Now that some of the overall elements of an obsolescence program have been reviewed, long term storage specifics should be considered. Long term storage presents many challenges. Some issues discussed earlier include the need for physical space and cost and warranty considerations. However, with appropriate care, ICs can be successfully stored long term at the die/wafer level or as finished goods packaged in plastic or hermetic format. Long term storage technically begins at the one year mark. In the commercial world, two years is considered long; whereas, in the military, space, and avionics fields, twenty years and beyond is quite common.

## III. COMPONENT STORAGE

Successful storage methodologies for die and wafers include special bagging, environmental controls and periodic monitoring. Proper storage requires care, cleanliness against particulates and gases, and benign temperatures. Integrated device manufacturers (IDMs) perform die banking but few

distributors do. A controlled atmosphere is created using “dry boxes” with dry nitrogen purged storage or dry bagged parts and vacuum storage. Oxygen barrier bags designed specifically for long-term storage should be used.

Storing at the die/wafer level provides several key advantages. First, the packaging is extremely compact so it requires little space. The container in Figure 2 holds nine wafers with a gross die count of 64,000. (Note Data CD for scale.) The form factor is also very flexible. Parts can be assembled into almost any desired package including packages which may not currently be available.



Figure 2 Die/Wafer Banking

Hermetic packaging minimizes moisture intrusion with 20 year storage times considered routine. Common hermetic packages include the metal TO-3 “can”, ceramic and side-brazed packages in DIP, LCC, flat pack, and PGA formats. The packages must be kept dry and in environments low in sulfur, chlorine, and hydrocarbons to preserve the solder finish on the lead frame.

Hermetic packages pose both disadvantages and advantages. Their package type cannot be changed and they are slightly more expensive to store than the die banking option. A large storage space is required; but, it is an easy storage infrastructure with long lifetime storage.

Misconceptions about plastic packaging are pervasive. Some organizations assume that since parts may come from the manufacturer in sealed packaging, they don’t require any further special handling or storage. Or, since some parts are not rated with moisture sensitivity levels (MSL) requirements, they are risk free and safe to store in any normal factory or

warehouse environment. Nothing could be further from the truth.

Plastic is hygroscopic in that it attracts water molecules from the environment. A plastic package can achieve moisture equilibrium in 4 to 28 days depending on the molding compound used (See Figure 3). Although it can take up to four days for a part to reach moisture equilibrium, it takes longer for actual damage to occur. A “normal” room environment is considered “wet” for plastic ICs. As an example, data from the LAX weather station collected over 30 years shows an annual indoor relative humidity (RH) average of +70%! So, plastic packages must be stored in moisture barrier bags (MBBs or “dry bags”) or in a <10% RH environment.

Certain industries, however, may be prohibited from using long term storage by regulations such as the Federal Acquisition Regulations (FAR). FAR often limits procurement to one or two years. Systems manufacturers for projects governed by FAR have rarely funded long-term procurement from their own budgets. This may be a situation where considering some of the managed supply options is useful in limiting financial risk and preparing for obsolescence.

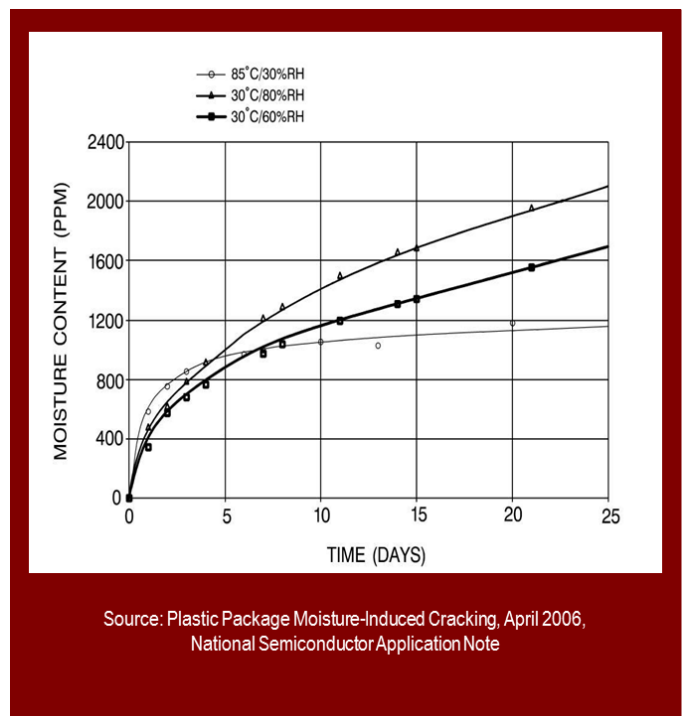


Figure 3 Moisture Equilibrium

Many people are surprised at the concept of a normal room as “wet.” But, they forget that in operation, a device is turned on, the die heats up and the moisture is driven out. Components, however, are not stored in a powered up condition. People also correctly state that water doesn’t hurt plastic. However, it’s not the plastic that is of concern; it’s the water. Water leaches or reacts with materials from the mold

compound, elements in the gases in the environment and other materials deposited on the outside of a package. Water also corrodes and degrades metal pads and wires which drives device failure.

Some plastic components are also rated as non-moisture sensitive. This rating is for IC/board assembly for reflow solder heat induced delamination and popcorning. Contrary to popular belief, it is not a rating for long-term storage.

Wafers, dice, and hermetic and plastic packages can be reliably stored for long periods of time. All must be stored in a clean, dry environment. Plastic finished goods also require periodic monitoring. Having stored components essentially eradicates the problem of locating end of life (EOL) obsolete parts in the future.

#### IV. LONG TERM STORAGE CASE STUDY

In this case study, solderability was assessed for components from three different reels that had been stored for up to five years in order to determine how much additional storage life was available. The components were either an ASIC in a SOIC package or a MOSFET in a TO-252 package. In both package styles, the lead frame plating was tin-based.

Knowing the plating material is critical since it drives selection of the appropriate solderability test. In this case, tin can either oxidize and/or form intermetallics with the base metal underneath. Both reactions can degrade the solderability of the component. To assess these reactions, the components were subjected to steam aging to accelerate storage related effects on solderability. The elevated temperature accelerates tin-copper intermetallic growth while the steam accelerates tin oxide formation. The components were then tested for solder wettability using a wetting balance test.

The steaming apparatus was constructed as per IPC-TR-464. The components were placed in the “dead bug” position on an inert and heat resistant polypropylene stage. The components were held at approximately 93°C, between 80% and 90% relative humidity (RH), and no more than 1 1/2" from the surface of the boiling water. Each day exposed to this accelerated steam aging method is considered to be equivalent to one year in storage. Three components from each reel were aged for 0, 12, 24, 48 and 72 hours, corresponding to 0, 0.5, 1, 2 and 3 years of additional storage.

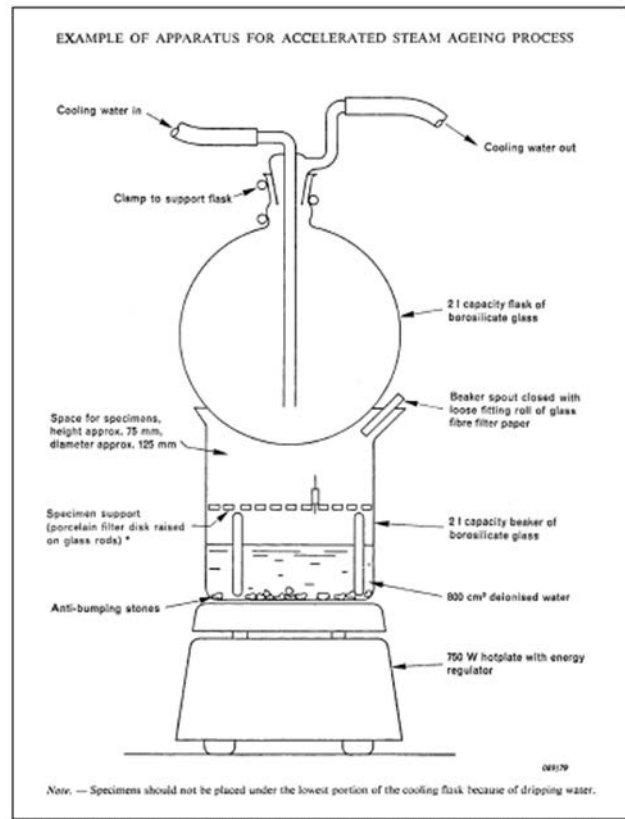


Figure 10 Steam Aging Apparatus, International Electrotechnical Commission (IEC), Publication 68-2-20, 1979, p. 41.

Figure 4 Steam Aging Apparatus

Measurements of the wettability of the leads were performed using a solder meniscus measuring device (wetting balance) for each component. All parts were tested with a standard rosin mildly activated (RMA) flux. The recommended procedure for this is detailed in IPC/EIA J-STD-002C. Three components from each reel were tested. The acceptance criterion from J-STD-002C is provided in Table 5 below with Set A criteria more stringent than Set B.

Parameter	Description	Suggested Criteria <sup>1</sup>	
		Set A	Set B
T <sub>0</sub>	Time to buoyancy corrected zero	≤1 second	≤2 seconds
F2	Wetting force at two seconds from start of test	50% of maximum theoretical wetting force at or before two seconds <sup>2</sup>	Positive value at or before two seconds
F5	Wetting force at five seconds from start of test	No less than 90% of the F2 Value	No less than 90% of the F2 Value
AA	Integrated value of area of the wetting curve from start of test	Area calculated using sample buoyancy and 50% maximum theoretical force <sup>3</sup>	> zero (0)

Table 5 J-STD-002C Criterion

#### Case Study Results

For the TO252 from production year 2003, solderability is already impaired (Figure 6). The dashed line indicates a part which was tested with a more active water soluble flux. Notice the significant improvement in wettability. This suggests that



the mechanism for poor wetting is a thick oxide rather than intermetallic formation.

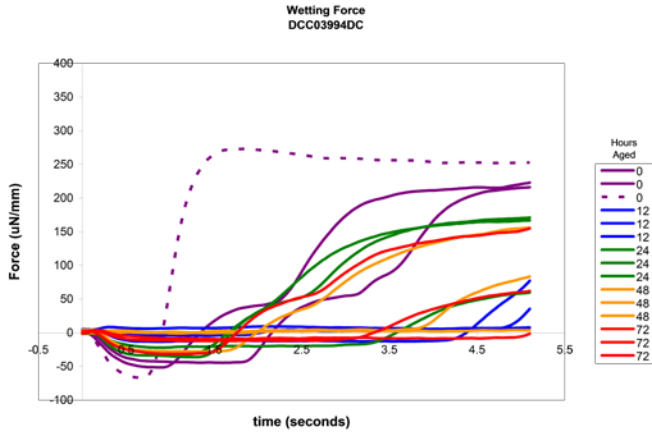


Figure 6 TO-252 2003 Results

Even though the TO252 from production year 2000 is older, its initial solderability is superior to the 2003 part (Figure 7). After 12 hours of steam aging equivalent to six months storage, the solderability has deteriorated.

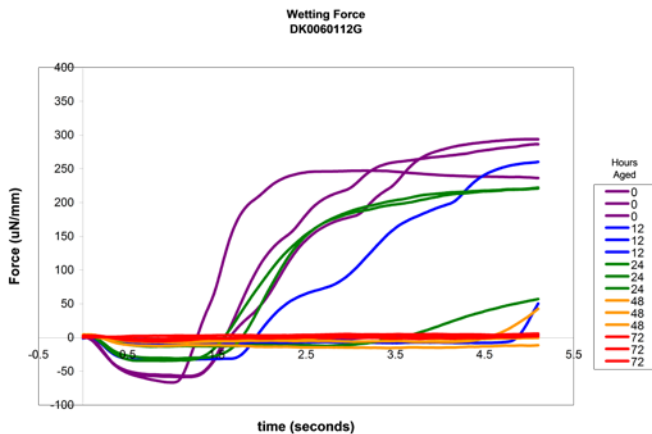


Figure 7 TO-252 2000 Results

For the SOIC (production year unavailable), solderability degrades slowly (Figure 8). The part does not become completely unwettable, like the TO252 parts, but it fails IPC criteria after 24 hours of steam aging, equivalent to 1 year of storage.

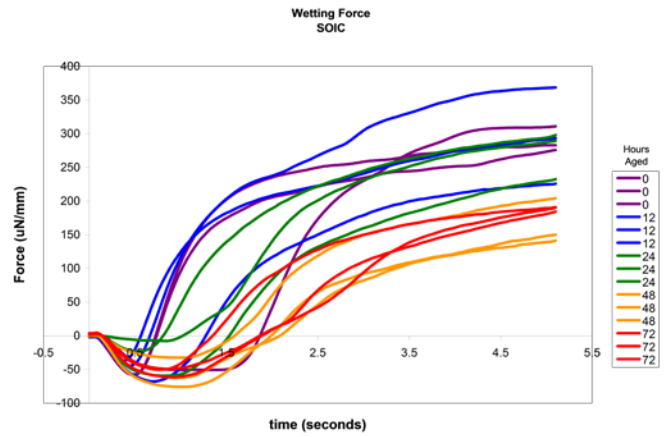


Figure 8 SOIC Results

The same components produced by the same manufacturer can display very different behaviors in regards to long-term solderability. This was seen with the TO252 parts where the parts fabricated in 2000 had better wettability than the parts fabricated in 2003. Therefore, any component or obsolescence storage strategy should involve an initial solderability assessment of each part and date code combination.

Any concern with poor solderability, if driven by oxidation formation, can be potentially mitigated through the use of more aggressive flux formulations. This may require contingency planning for assembly of components after long-term storage, including movement to more active flux chemistries and introduction of modified cleaning processes to ensure these chemistries are effectively removed after soldering. The study also clearly demonstrates that the most critical parameter to control during long-term storage is temperature since oxide formation can be potentially remedied while intermetallic formation cannot.

### V. STORAGE RELIABILITY ISSUES

Additional long term storage reliability issues to consider include intermetallics/oxidation, stress driven diffusive voiding, moisture, Kirkendall voiding, and tin whiskering.

#### Intermetallics/Oxidation

Intermetallic compounds form when two unlike metals diffuse into one another creating species materials which are combinations of the two materials. Intermetallic growth is the result of the diffusion of one material into another via crystal vacancies made available by defects, contamination, impurities, grain boundaries and mechanical stress. There are a number of locations within the electronic package where these dissimilar metals are joined. These include die level interconnects and wire bonds, plating finishes on lead frames, solder joints, flip chip interconnects, etc. Growth of intermetallics during the storage period may occur and may reduce the strength. Growth may also increase the resistance of the interconnect due to the properties of the intermetallic or due to Kirkendall voiding.

Intermetallic layer thickness can be estimated by following equation:

$$X = Kt^{1/2}$$

Where X is the intermetallic layer thickness, t is the time and K is the rate constant which is calculated by following:

$$K = Ce^{-E/KT}$$

Where C is the rate constant (there are nine different ones listed by Philofsky), e is the activation energy (typically 0.4 to 0.9 eV), K is the Boltzmann constant, and T is the temperature in absolute scale. So, modeling and prediction can be performed for this mechanism.

Stress Driven Diffusive Voiding in on-die interconnects results from the mismatch in coefficient of thermal expansion between the dielectric layers and the metallization itself. Aluminum has a very high coefficient of thermal expansion (~27 ppm/°C) while SiO2 has a fairly low coefficient of thermal expansion (~4 ppm/°C). Since metal deposition operations during semiconductor manufacturing are performed at elevated temperatures, the metallization contracts as it cools, causing it to be in tensile state. These tensile stresses relax over a period of time resulting in small movements (diffusion) of metal atoms. This movement can result in a void or an open interconnect. Compressive stresses from the molding process can also cause movement of metallization atoms. This can cause thinning of the interconnect resulting in greater current densities during operation. These current densities may be sufficiently high to cause electromigration which can also lead to an interconnect open.

A tin whisker is a single crystal growth that can occur on tin plated lead frames (See Figure 9). The mechanism for the growth is not clearly understood but it does appear to be related to compressive stresses in the plating, moisture, and contamination. This may be an issue for alloy 42 lead frames with pure tin platings since large compressive stresses are present due to the CTE mismatch between the alloy 42 and the tin. Tin whiskers can lead to shorting, intermittent errors, and high frequency issues.

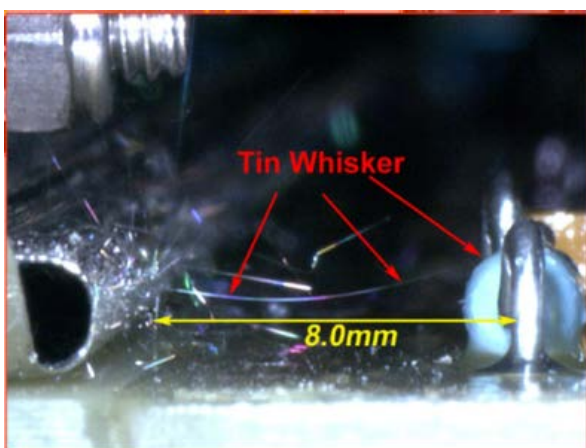


Figure 9 Tin Whiskers

Depending on storage time and conditions, parts may be subjected to moisture. This can occur due to overloading of the desiccant with moisture, failure of the storage bags, or improper storage. The presence of moisture can lead to corrosion issues and other failures such as popcorning during subsequent soldering operations.

Printed Circuit Board Storage requires some unique storage considerations. Common Pb-free board final finishes include Electroless nickel/immersion gold (ENIG), Immersion tin (ImSn), Immersion silver (ImAg), Organic solderability preservative (OSP) and Pb-free HASL. If SnPb HASL plated boards have historically been used, the biggest change will be to allowable storage times. Except for ENIG, which many companies avoid because of cost, and perhaps Pb-free HASL, all alternative Pb-free platings should be limited to 12 months of storage. Studies for the storage life of Pb-free HASL platings are underway with some showing 2-3 year storage life or better. Over time, ImSn will form intermetallics (temperature), OSP-coated copper will oxidize (humidity), and ImAg will tarnish (gaseous sulfides). OSP-coated boards may potentially be reworked once or twice but ImSn and ImAg finishes may not. Once these have degraded, they must be scrapped.

Another potential issue with board plating that involves solder is Kirkendall voiding (Figure 9). This occurs when voids form at the interface between two dissimilar materials due to differential diffusion. If these voids coalesce, solder joint failure is more likely, especially under mechanical shock/drop conditions.

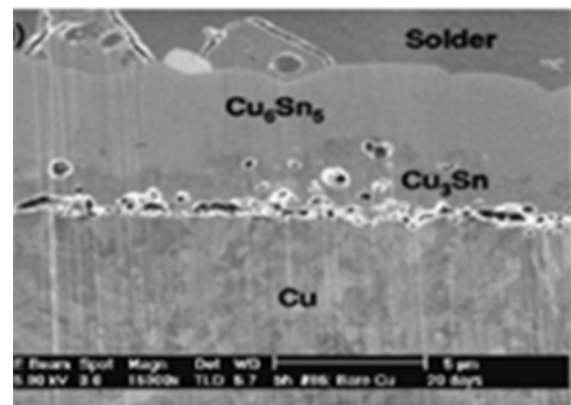


Figure 10 Kirkendall Voids at Interface

## VI. CONCLUSIONS

In summary, managing component obsolescence issues is critical to long term reliability. Companies producing high reliability, long life products should anticipate and plan for obsolescence by implementing a robust management program which considers:

- Asset Security
- Component Inspection
- Product genealogy (origins) & condition

- Storage Environment
- Data Management
- Assured Supply
- Potential reliability issues

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