LONG TERM STORAGE
OF
ELECTRONIC COMPONENTS

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Abstract

Long term storage, particularly of last time buy components, has been proposed as one solution to the problem of component obsolescence.

The ALTER Technology Group (ATG) is in a unique position to report on this concept and advise the best way to manage long term storage and eliminate associated reliability problems.

ATG has been storing EEE components since 1982 and a decision to scrap many of these components has provided the opportunity to perform in-depth analysis of product with a fully documented history.

This presentation will also describe “relifing” procedures and optimal storage conditions.

Introduction

ATG became involved in long term storage because a European Space customer could not work with the very long lead delivery times being quoted by EEE component manufacturers for space quality components.

As a result of a change of policy by this customer ATG were left in a unique position to study the effects of long term storage on a wide range of EEE components.

The storage conditions used will be described as will the storage conditions used successfully for PEMs (Plastic Encapsulated Microcircuits).

The concept of relifing will be described.

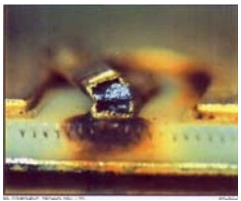
The concept of kitting, ie storing a complete set of components for a specific circuit board will be outlined.

Background

The initial motivation for long term storage was to supply components to support on-going programmes and programmes with maintenance and refurbishment requirements. A situation more closely aligned to the scenario of aircraft and military system manufacture & maintenance.

The space industry places great importance on recording every problem encountered. Non-conformances abound and invariably result in a full failure analysis investigation being undertaken. There were no records of NCR’s relating to product from long term storage.

Long Term Storage May Not Be Easy



This illustration shows how component leadouts may degrade in a very short space of time. This product was stored by a UK user in an approved space level assembly area.

The nickel-iron leadout has been completely corroded leaving only the gold and nickel platings. The component was stored “normally”, failure occurred within two years of the component’s date code.

The component was a “drop in isolator” from a major qualified manufacturer. The user was a major aerospace equipment manufacturer based in England.

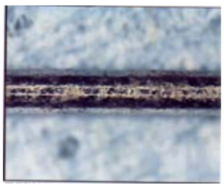
“Normally” means a typical store area in the UK with no specific environmental controls but a temperature and humidity range within the UK norm. The product was stored in the component manufacturer’s original packaging.

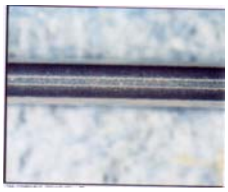
Was the problem with the storage or the component?

In this case the leadout is brazed (a.k.a. silver or German soldered) to the package. The fluxes used are corrosive. This is a widely used process and is totally reliable if the fluxes are correctly neutralised. ATG’s experience is that for many years a component manufacturer can achieve excellent results but a change in the “mix” of personnel, location, facilities etc., can cause aberrations, like poor flux removal, which result in failures like the one shown above.

Relifing

Relifing of EEE Components is a normal practice in the manufacture of spacecraft electronics and involves the routine periodic testing of stock. The process is described in ECSS-Q-60B and may include optical inspection, solderability testing and destructive physical analysis. Typical problems noted during relifing are degradation of lead finish: -





A typical solderability problem found at relife and the reworked component.

Degradation of solder coated leadout finishes is the most commonly reported problem during relife.

Often the degradation is only cosmetic and the components pass solderability testing.

Occasionally failures are found which show severe dewetting and will need rework and retest before being considered usable.

Degradation with time of lead tin solder finishes is an expected phenomena but the observed degradation has never been as severe as many authorities suggest.

The ATG Long Term Storage Study Samples

A total of 100 Component Types were available, including: -

- Microcircuits
- Transistors
- Diodes
- Switches
- Xtals

The component sources were qualified to: -

- MIL-M-38510 Class S
- MIL-S-19500 (JANS)
- ESA/SCC Level B etc.

Note 1. MIL-M-38510 Class S is considered to be the highest quality microcircuits available from a military component supplier which is equivalent to an ESCC Level B microcircuit.

Note 2. Similarly JANS transistors are equivalent to ESCC Level B Transistors.

The components used for the study were selected to give the greatest variety of package style and component manufacturer.

Five units of each component type were allocated to the study.

The documented history of each component was also available for review.

The ATG Long Term Storage Study Procedure

Each component selected was subjected to: -

- External Optical Inspection
- Electrical Parametric Tests
- Fine and Gross Leak Hermeticity Tests
- Solderability

and on a sample basis:-

- Residual Gas Analysis (RGA)
- De-encapsulation
- Optical and SEM Inspection
- Wire Bond and Die Shear Strength Testing

The rational for each test is as follows: -

- External optical inspection to look for signs of corrosion and degradation of the component finish are the first element of the study.
- Electrical parametric measurement to identify possible handling induced failures and performance degradation (by comparison with the original documentation).
- Degradation of hermetic seals has long been a claimed cause for concern and seal integrity is verified before de-encapsulation or RGA.
- Solderability to identify degradation of solder finishes both on copper leadouts due to the formation of copper tin intermetallics and on nickel plate due to the formation of tin rich oxides.
- Performance of residual gas analysis (RGA) on a sample basis to establish if any transfer of internal to external atmosphere has occurred.
- De-encapsulation performed using the least destructive techniques available.
- Optical and SEM inspection to permit internal examination for time dependent failure mechanisms, eg corrosion and the development of intermetallics.
- Wire bond and die shear strength testing to support the optical and SEM inspections.

The ATG Long Term Storage (LTS) Study Results

The results may be briefly summarised as: -

- 100 component types were tested.
- No electrical failures were identified.
- No parts failed solderability testing. Ratio of gold plated to solder dipped leadouts 40/60.
- One component failed fine and gross hermetic seal testing.
- One component failed residual gas analysis.
- No internal defects were found.

Considering the hermetic seal failures: -

- This occurred on a MIL-S-19500 transistor in a TO63 package.
- 1 of 5 samples was reported to fail fine and gross leak testing.

- The helium fine leak test result was: -

  3.3×10^{-7} atms. cm^3/s

  the acceptable limit is: -

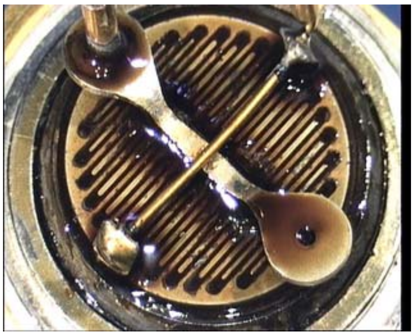
  5.0×10^{-8} atms. cm^3/s

- The fluorocarbon coarse leak test showed bubbles coming from the "gap" between the weld and the header.

TO63 Package

Coarse Leak
"Failure site"

- After de-encapsulation the die posts and emitter base connections were found to be coated with a "barrier lacquer". Note this construction did not use wire bonding connections.
- There was no evidence of fluorocarbon in the de-capped part.
- It is strongly suspected that the leak detected was from a void in the seal area which did not penetrate into the cavity.
- The barrier lacquer would have minimised any reliability hazard.



It is unlikely that this part would have been degraded by an hermetic seal failure.

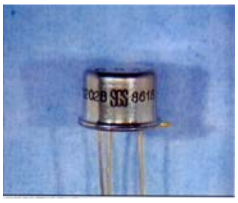
Considering the RGA failure: -

- This occurred on an ESCC qualified bi-polar transistor.
- The results were: -

  Water Content – 6785 ppmv Acceptable Limit - <5000 ppmv
  Nitrogen – 99.14%[1]
  Dewpoint – 1.7°C[2]
  CO_2 – 599 ppmv[3]
  Other masses - <66 ppmv[4]

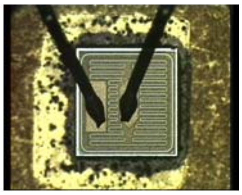
Note 1. The nitrogen content is good.
Note 2. The dewpoint is high, typically <0°C would be expected.
Note 3. The CO_2 content is good.
Note 4. The other masses – argon, hydrogen, oxygen and helium are good.

- RGA testing was repeated with two additional components with satisfactory results.
- After de-encapsulation Optical and SEM inspection of the de-capped part found no evidence of corrosion.



TO5 Package

De-capped TO5



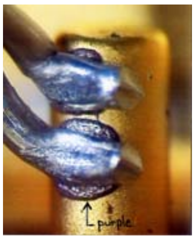
Die Surface

- The die was glassivated.
- The bond wires are aluminium but are 175µm (7mil) in diameter so corrosion is less of a problem. The wire bond strength test results were good. The mean value recorded of 166.56gmf is typical of results still being seen today from the same manufacturer and the same combination of die and bond wire. The distribution of failure sites is equally unchanged. All failures occurred at the "neckdown" point at the die and post which is expected.
- This component is also not considered to be a potential reliability hazard.

Gold Aluminium Intermetallic

The development of gold aluminium intermetallics is a major factor in semiconductor reliability. The majority of the product covered by this study has aluminium bond wires and aluminium die metallisation. Gold and aluminium are only found in contact on bi-polar transistors with gold plated headers and posts and microcircuits with gold plated package lands.

Gold aluminium intermetallics are found where aluminium wire is bonded to gold plating. ATG have undertaken evaluations to prove that this phenomena is not a potential reliability hazard at gold plated surfaces.*[1] However, comparisons were made where possible to support these conclusions.



Comparison of a five year old DPA Report with a similar product from the LTS study.

- Tweezer bonds or welds are commonly found on bi-polar power transistors. The distinctive purple phase of gold aluminium intermetallics is often present at the periphery of the weld.
- This component had 150µm (6mil) aluminium wire. Wire bond strength testing gave results from 119gmf to 200gmf (Limit >50gms). Four results were characterised by the wire "peeling" from the die surface. This is not considered to be unusual for power bi-polar product. The other results were in the wire length or at the neckdown points. Also considered to be normal. No failures occurred at the bond to post interface.

The absence of any degradation after 18 years is considered to justify the conclusions of ATG's earlier evaluations.

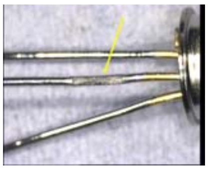
Long Term Storage Conditions – The Study

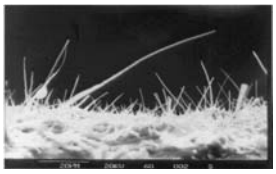
The product available for this study had been stored in: -

Clean Room	-	Class 10,000
	-	Temperature, 22±3°C
	-	Humidity, 55±10% RH
Packaging	-	Mainly from original component manufacturer

It must be noted that the practice within the European space industry is to procure components which are individually packaged. Where this has not been possible ATG has repackaged components individually.

Although outside the scope of this study ATG has experience of degradation of the component lead finish caused by the antistatic coating of the manufacturer's packing: -





Some "antistatic" materials achieve antistatic properties by virtue of a conductive coating or film applied to the surface of the packaging material. In this instance the lead/tin solder on the leadouts has reacted with the coating. The lead has been consumed in the reaction leaving a tin rich area. Tin whiskers were found in this region and a tin oxide has developed which was found to be unaffected by non-active organic fluxes and "acceptable" inorganic fluxes making the parts unsolderable.

Long Term Storage Conditions – PEMs and PEDs

This study described the evaluation of hermetically sealed components subjected to long term storage. Can the results be read across to plastic encapsulated microcircuits (PEMs) and plastic encapsulated diodes and transistors (PEDs)?

Considering the significant differences between hermetic microcircuits and PEMs: -

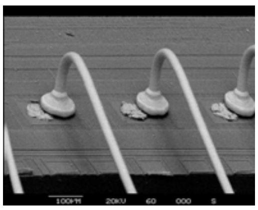
- gold bond wires to aluminium metallisation (Au/Al intermetallics).
- tin or tin/lead (Sn/Pb) leadout finishes on unpassivated copper leadouts (CuSn intermetallics).
- moisture sensitivity of the encapsulant.

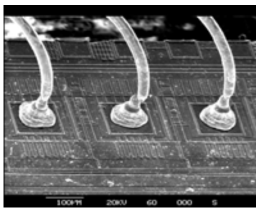
To achieve the same LTS results as those for hermetically sealed product ATG consider some additional precautions are necessary: -

- Individual antistatic package.
- Vacuum sealed in dry nitrogen after 48 hour stabilisation bake at 85°C.
- With: -
  - Desiccant
  - Moisture Indicator
  - Appropriate Labelling

Stabilisation bake for 48 hours at 85°C is recommended although other authorities and agencies recommend 24 hours at 125°C. Both gold/aluminium and copper/tin metallics*[2] are temperature dependent and the rate of development is exponential. In ATG's experience the "knee" of the gold/aluminium intermetallic graph occurs around 125°C.

Are these precautions necessary: -





"Popcorning" due to moisture ingression causing two very different failures.

- Popcorning is the result of the extremely rapid vaporisation of any moisture in a plastic encapsulation during soldering. The pressure generated by this vaporisation may exert sufficient force on the component to wrench gold ball bonds from the die surface or to tear bond wires apart.

- In the left hand image the gold ball has failed. The ball has sheared through the intermetallic leaving some intermetallic attached to the die bond pads.
- In the right hand image the gold wire has broken.

Does the storage process for PEMs work?

Overage from the qualification of a GPS PEM was stored for 2½ years as described above. RGA was performed on two of the antistatic bags used to store the parts. The results were: -

Water Content	-	7000-8000ppmv
Nitrogen Content	-	89-92%
Oxygen Content	-	5-7%
CO_2 Content	-	3700-4900ppmv

Clearly these results are not as good as would be expected from the inside of a packaged hermetic component but when read with the results below are an indication of the effectiveness of the process.

The overage was also subjected to a 100% parametric testing and 100% optical inspection. No failures were found. The parts were shipped to the user and are now in orbit.

Long Term Storage and Kitting

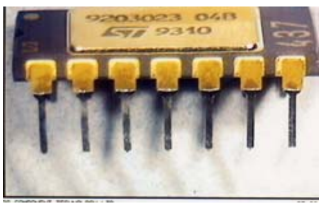
Why stop at storing individual components?

European space and industry practise has long been to have centralised procurement and to supply each subcontractor with a complete “kit” of the necessary components.

ATG has successfully expanded this approach to supply the needs of one major military/aerospace manufacturer.

Kitting could easily be applied to the long term storage of components intended for obsolete systems.

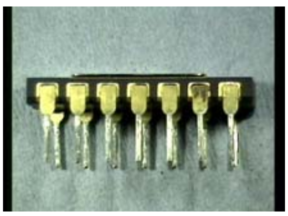
Other Users Problems

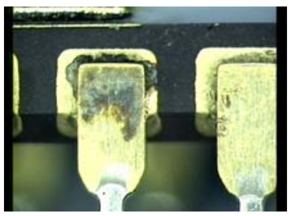


- This localised discolouration of the plating of side brazed ceramic microcircuits was first reported in 1982. Extensive analysis indicated only a cosmetic anomaly having no effect on form, fit or function.

- The problem occurred sporadically for the next 12 years.

- The European space qualified manufacturer bypassed the problem by changing the PID (Process Identification Document) to make such anomalies acceptable. The Europe space industry users simply made it a Purchase Order condition that no parts with this anomaly be delivered. Of course users not on the circuit were unaware of the existence of the anomaly.





The Results of Storage in Uncontrolled Conditions for 10 years.

- This component was from the same manufacturer as the previous sample reported by ATG. The date code was 9024.

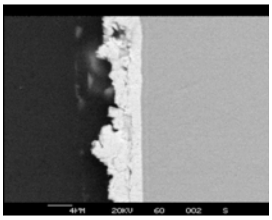
- Extensive discolouration of the shoulders of **some** leadouts was evident.

- Two samples were made available to ATG both were subjected to solderability testing and both passed.

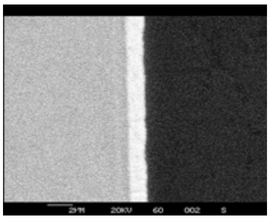
- A selection of leadouts from one component were subjected to terminal strength testing including: -

Pin 14 - heavily discoloured – 50 x 90° cycles, no failures.
Pin 13 - "clean" – lead broke below shoulder – 40 cycles.
Pin 1 - "minor" discolouration – lead broke below shoulder – 42 cycles.
Pin 2 - "clean" – lead broke below shoulder – 39 cycles.

- Leadouts from the other component were subjected to microsectional analysis.



"Anomalous" Leadout in Microsection



"Good" Leadout in Microsection

- Microsectional analysis of the "anomalous" leadout when compared to the "good" leadout showed a very uneven finish to the gold plating. This phenomena had not been previously seen.

- Historically the discolouration had been attributed to a "phase separation" of the copper and silver in the brazing material (used to attach the leadout to the package) involving atmospheric sulphur dioxide, resulting in the development of silver sulphide in the gold plating. This reaction was known to be time dependent.

Conclusions

Long term storage under appropriate conditions does not cause degradation of components.

Long term storage is an obsolescence solution particularly for "last time buys".

Long term storage is a practical solution where COTS, PEMs and PEDs have been upscreened.

References:

*[1] *Gold Aluminium Intermetallics, The Saga Continues, Harvey, Jones, Fidler, EMIT-2K, Bangalore, India.*
*[2] *Copper/Tin Intermetallics, O'Donoghue, Microtech 2005, UK.*