

Component Quality Defects: Identification, Investigation & Remediation

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Abstract

Supply chain is at the top of a list of critical issues with which all assembly lines deal. Cost, lead times and quality are the primary components of that issue. Cost and lead times are both visible and able to be planned for before components ever reach the production floor, but the effect of the quality of incoming material is one that is sometimes learned the hard way. Supplier quality controls do not always discover all manufacturing defects, so it is up to assembly houses to work in conjunction with component manufacturers to improve the quality of incoming material to benefit all parties involved once an issue is discovered. Of course, these types of issues are the worst case scenarios because they are often not found until after cost sensitive components are assembled, especially when changing component vendors.

A specific case is discussed where component quality issues did not present themselves until assembly in-line hermeticity testing and final visual inspection discovered them. A decrease in hermeticity yield prompted an investigation which revealed package manufacturing defects that caused leaking between the package castellations. Additionally, at final inspection, a previously unseen discoloration on a few package leads led to an investigation that revealed a problem with a plating process that resulted in thin gold plating, thus allowing nickel to oxidize on the surface during assembly heating processes. The details of the investigation are discussed and followed on by the ensuing discussion with the vendor and change in vendor processing is presented.

Keywords: CERMET, hermeticity, thin gold, nickel oxidation, component quality, supply chain

Introduction

Changing vendors or beginning the use of new components is inevitable and even necessary for survival in the microelectronics field. The harsh environments encountered and need for absolute reliability in certain applications dictate that quality be among the highest of concerns when undertaking these tasks. It is for these reasons that so many resources are devoted to quality management and quality control systems such as ISO and MIL-STDs that qualify and integrate these new components into new and existing processes. Unfortunately, due to the high number of variables encountered in both vendor and assembly processes, not all quality defects are found during component qualification and do not present themselves until after volume production has already started.

We were required to integrate an LCC40 CERMET package produced by a different manufacturer than was being used in production at that time. First, this new package underwent and

passed component qualification and product testing in accordance with MIL-STD-883. After qualification acceptance, the package was released to production where we then experienced unexpected yield losses. We realized as high as a 5% hermeticity yield loss in addition to a 4% yield loss at final inspection. The final inspection defect of concern was a discoloration on gold plated castellation leads. In the best cases, the two defects combined for only a 2% cumulative yield loss; however, the combined yield losses varied with manufacturer component lot and ranged as high as 9%. Due to the nature of these failures, the reliability of the passing devices was in question. This reliability concern, in combination with the always present need to improve assembly yield by eliminating these failures, initiated investigations to determine their causes.

Investigation

These yield losses were not discovered during component/vendor qualification due to the sample size required for MIL-STD qualification being relatively small. During the qualification, the in-line assembly hermeticity yield loss was well within expected levels for this assembly process and no lead discoloration was found at all. Therefore, there were no problems with the data from the assembly process and the subsequent reliability screenings did not reveal any problems because any problematic devices had already been screened out by assembly in-line screens. These specific defects, if not present by the end of the assembly process, do not manifest themselves during reliability testing. It was not until full production started that these defects were discovered.

Due to their higher prevalence and possibly greater impact on reliability, the first investigation was initiated to uncover the cause of the hermeticity failures. Helium mass spectroscopy and perfluorocarbon detection methods were used for fine leak and gross leak testing respectively with both failure types being discovered. Subsequent OLT (optical leak testing) confirmed these results as valid and repeatable between testing methodologies. Both methodologies were employed following the guidelines set forth by MIL-STD-883, Test Method 1014.12. Those devices failing fine leak testing were also sent on for perfluorocarbon gross leak testing and then visually inspected.

Visual inspection of the perfluorocarbon bombed devices showed perfluorocarbon leaking from the sides of the package when pressure was applied to the lid, thus indicating that at least some of the leak test failures were not due to compromises in the solder seal, but instead to the package itself. In the most severe cases, separation between the castellations was readily evident under a magnified view.

The second issue investigated was discoloration found on package leads at final visual inspection. This discoloration was found on varying numbers of leads per package in addition to bond fingers internal to the package cavity. This discolored gold was proven to be an unsolderable surface in addition to an unbondable surface for aluminum wedge bonds.

Of course, understanding the technical aspects of these problems was only the first set of actions as one must then undertake the job of working with the manufacturer in order to remediate the problems so that the quality of incoming material is improved, thus resulting in a benefit to both sides.

Interpretation

Failure analysis of the hermeticity failures showed two distinct failure modes. The first mode is shown in Figure 1, where a visually distinct separation can be seen in between the top castellations where the vertical lead plating ends. This mode of failure was seen on gross leak failures only, with a gross leak failure being defined as having a leak rate of less than 1×10^{-5} cc-atm/sec of He as calculated using OLT testing.

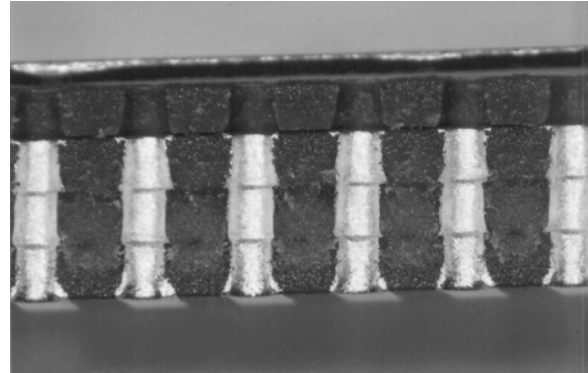


Figure 1: Gross leak hermeticity failures were predominantly due to separation in between castellations. This image shows complete separation of the top layer.

The second failure mode was found on both gross and fine leak failures where the hermeticity was compromised between the package castellations only at the lead seal. The ceramic regions separating the leads visually appear to be solidly connected. Bubble leak testing was used to locate the source of the leaks, which can be seen in Figure 2. SEM images were also taken in an attempt to pinpoint the source of the castellation leaks; however, as can be seen in Figure 3, there is no readily identifiable compromise in those locations.

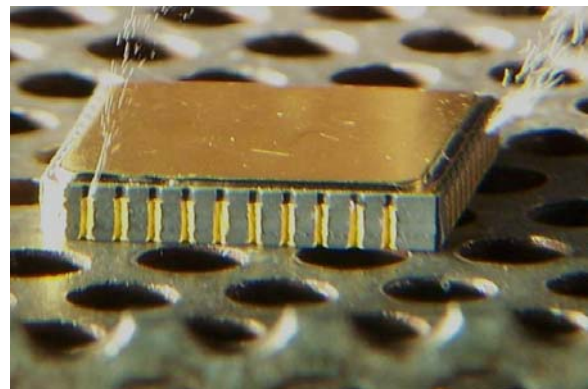


Figure 2: Bubble leak testing picture showing leakage from castellations only at the lead seal.

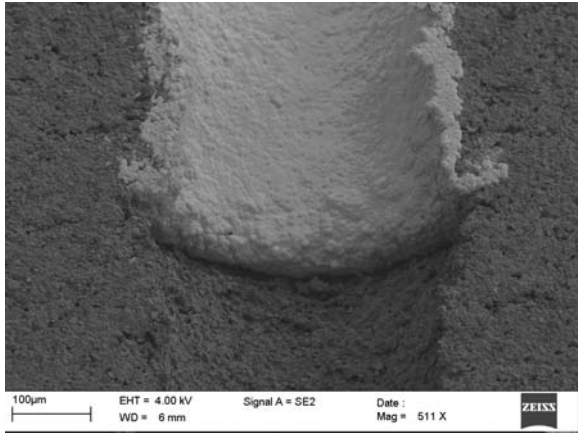


Figure 3: SEM image of location of leaking castellation showed no observable hermeticity compromise.

A visual image of the lead discoloration is shown in Figure 4 as it was found at assembly final visual inspection. Upon finding this defect, the process was broken up and visual inspections were performed at each step in order to determine where in the assembly process this defect was being created. We found that this discoloration would only occur on the leads after two or even all three heat cycles seen throughout the assembly process with the highest peak temperature reaching 410 C. No one heat cycle alone caused this visual defect, but was found to be a cumulative process. For this reason, an internal screening plan could not be implemented due to the large time commitment in addition to the potential reliability impact on temperature cycling these packages.

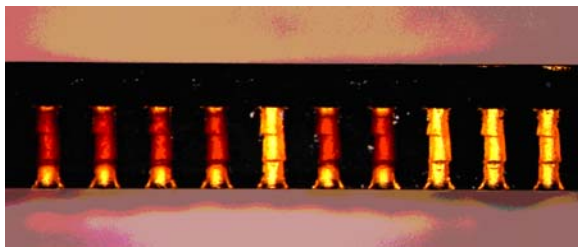


Figure 4: The observed discoloration was analyzed and found to be nickel oxide.

It should be noted, that only one heat cycle was needed for the same defect to occur on the package bond fingers as seen in Figure 5. This manifestation was rarely seen and is only mentioned for completeness and evidence of the encompassing nature of the root problem.

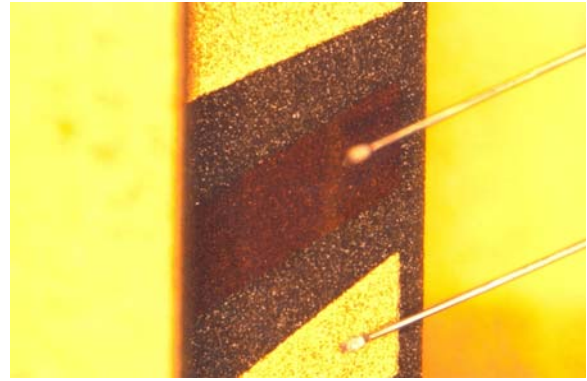


Figure 5: Nickel oxides were also found on bond fingers in the package cavity.

Cross-sectioning and SEM imaging revealed that the gold plating thickness was inconsistent, even between leads on the same package. On leads whose appearance remained golden, the gold thickness was within spec according to the manufacturer's drawing ($\geq 2.54 \mu\text{m}$) and varied from 2.5 -5.0 μm ; however, on those leads that were discolored, the gold thickness was found to be well below the manufacturer's spec and varied from .5 – 1.5 μm . Thin gold plating did not provide sufficient protection to the underlying nickel layer and allowed the nickel to diffuse and oxidize during the heating cycles of the assembly processes.

A cross sectional view of a non-oxidized lead is shown in Figure 6. A full thickness gold layer ($\sim 4.8 \mu\text{m}$) can be seen on top of a discrete and identifiable nickel layer. This is in contrast to the discolored lead seen in cross section in Figure 7 where the gold layer is extremely thin (.65 μm) and there is no defined nickel layer.

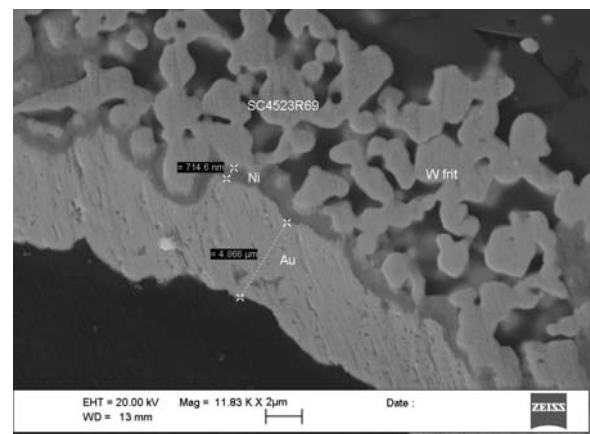


Figure 6: Higher magnification SEM image showing in spec Au plating thickness on a lead.

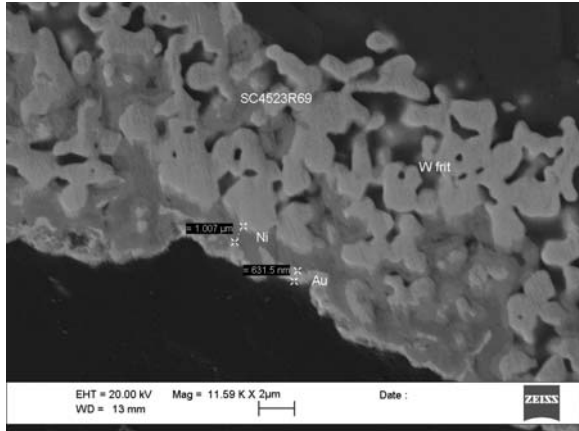


Figure 7: This SEM image shows a very thin Au layer and an indistinguishable Ni layer.

Interestingly, it is possible that these two problems are linked. The hermeticity compromise in the package could change the plating solution flow characteristics, thus changing the deposition rates and subsequent plating thicknesses. We have not found any direct correlation to packages that fail hermeticity also exhibiting nickel corrosion; however, these packages are plated as a panel and a hermeticity compromise in one package could affect the plating behavior of neighboring packages.

Remediation

As this problem was not one that could be fixed internally, but instead required engagement with the manufacturer to begin working toward resolution, the first step was to supply the manufacturer with all of the data we had up to that point. Yield data, optical images, SEM images, plating thickness measurements and information regarding the assembly heating processes were supplied to the vendor as a starting point to resolving this problem.

The manufacturer then conducted their own testing under the charge of their own Material Review Board to show repeatability of our results and verify our findings.

After months of testing and interaction with the manufacturer's technical staff, the following changes were made to their processes and specs for this specific package:

1. The nominal lead gold plating thickness was increased from 2.54 μm to 3.05 μm .
2. The array layout was changed to change the shape of the plating through holes in order to increase the flow of plating solution in these areas.

3. The sampling rate plan for hermeticity was increased.
 - a. A process change has not yet been implemented to correct the root cause, but is being investigated.

The improvement to component quality and the resultant change in assembly yield has yet to be determined independently of the manufacturer; however, the limited data that has been provided thus far indicates improvement; however, we do not currently have anything quantitative on which to report.

Conclusions

Assembly houses undertake the expensive, time-consuming, yet necessary task of performing reliability testing prior to the incorporation of new components into their processes, yet this testing cannot be expected to find all component quality issues prior to production. It is almost a certainty that all assembly houses will encounter an incoming material quality issue that impacts their assembly yields to varying degrees. Rather than simply sending material back and pointing a finger, it is in the best interest of everyone for a collaborative approach to be employed that will ensure an improved product for the manufacturer to offer and for all assembly houses to use. Most importantly, it creates a partnership in industry that will be mutually beneficial to all in the future.

Recognition

Sincere thanks to the staff in RA & FA for the thorough analytical work as well as thanks to my colleagues for their constant support.

Biography

The author received a B.S. in Materials Science & Engineering from the University of Maryland in 2001. He began working for the Department of Defense in 2001 as a packaging research engineer and has since moved on to working in a production oriented packaging center. He is also a U.S. patent holder.