

ENGINEERING PRACTICE STUDY

TITLE: Bi-Metallic Wire Bonds for QML Device Classes V and P (class level S) under MIL-PRF-38535.

March 27, 2025

EP Study Project Number: 5962-2024-002

Final Report

**Study Conducted by DLA Land and Maritime
Document Standardization Division (VA)
Active Device Branch (VAC)**

Prepared by:

**Rodney Chambers
DLA Land and Maritime -VAC
Email: Rodney.Chambers@dla.mil
Phone: 614-692-9460**

DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited.

Bi-Metallic bonds for Classes V and P (class level S) devices under MIL-PRF-38535.

- I. **OBJECTIVE:** The purpose of this Engineering Practice (EP) Study is to obtain input/feedback from the military services, microcircuit manufacturers, package assembly houses and user communities regarding the allowance of bi-metallic bonds in class V and P devices under the MIL-PRF-38535 specification.
- II. **BACKGROUND:** According to MIL-PRF-38535 paragraph A.3.5.5.2 classes V and P (class level S) microcircuit devices currently require monometallic wire bonding, where the internal lead wire shall be the same metal as the die metallization. However, with technology progressing, especially with smaller die pad sizes, raise concerns about wire size issues and potential overlaps with the active region of die metallization during monometallic wedge bonding. To address these concerns, this engineering practice (EP) study was initiated to obtain feedback from the military services, microcircuit manufacturers, package assembly houses and user communities for leveraging bi-metallic bonds as a solution.

In the pursuit of leveraging bi-metallic bonds in microcircuits devices, it is crucial to address potential challenges such as the significant concern in accelerated advancement scenarios of migration of atoms across the bi-metallic interface can create voids or vacancies, weakening the bond (i.e. formation of Kirkendall voids or intermetallic compound IMC growth) that can lead to bond failures and compromise the integrity of microcircuit devices. Research indicates that factors like wire bonding temperature, alloy composition, bonding technique and workmanship play critical roles in managing these challenges.

The EP Study is available at:

<https://landandmaritimeapps.dla.mil/programs/milspec/ListDocs.aspx?BasicDoc=5962EPStudies>

DLA Land and Maritime-VAC is requesting interested stakeholders to review all attachments for future discussion and development.

(Attachment # 1) – Issues with Monometallic wire bonds in class V and P (class level S) of MIL-PRF-38535.

(Attachment # 2) - Feedback summary

- III. **RESULTS:** This EP Study project was initiated, and an initial draft was made available online and distributed to JC-13, CE-12, Government Working Group (GWG) and members of the space community on April 09, 2024, for review and comments. Feedback was solicited from all relevant stakeholders, including military services, microcircuit manufacturers, microcircuit distributors, original equipment manufacturers (OEMs), and user communities regarding the use of non-monometallic wire bonds in class level S microcircuits of MIL-PRF-38535.

Comments were received from three device manufacturers and three OEM / user organizations. The feedback was received and summarized herein attachment # 2. The results and comments were reported for discussion at the JEDEC conference Meetings on May 21, 2024, September 17, 2024, and on January 28, 2025. As a result of these discussions, a motion was approved to form a dedicated task group, to further explore and define qualification criteria for (non-monometallic) gold to aluminum wire bonds for Class V of MIL-PRF-38535.

- IV. **CONCLUSIONS:** The feedback received did not reach consensus approval for allowing (non-monometallic) Gold Wire to Aluminum Bond pads for Class V of MIL-PRF-38535. The initial EP Study topic will undergo further review and discussion for consensus-building through the JEDEC Task Group #25-02. A feedback summary on the comments received are summarized for review in attachment # 2.
- V. **RECOMMENDATIONS:** DLA Land and Maritime recommends all military and industry representatives review the comments summarized in attachment #2. DLA Land and Maritime recommends the JEDEC Task Group #25-02 assist in determining qualification criteria for non-monometallic (Au/Al wire bonds) in MIL-PRF-38535 Class level S microcircuits.

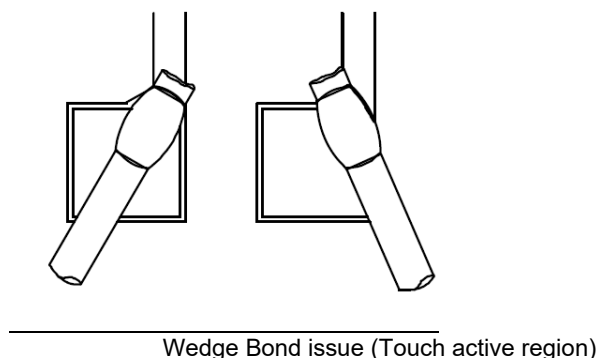
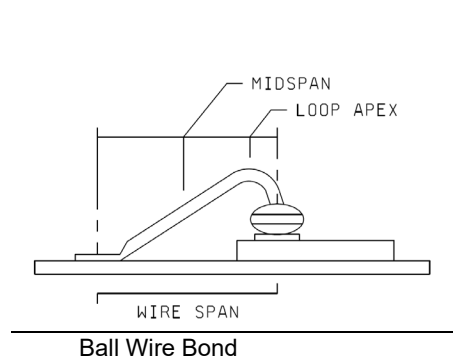
ATTACHMENT # 1

Issues with Monometallic wire bonds in class V and P (class level S) of MIL-PRF-38535:

The goal of this EP study is to find out standard practices for high reliability part manufacturers and use them to mitigate the Bi-metallic bond risks in the parts.

Issues/concerns:

- Smaller design of die pad sizes in advanced complex microcircuits devices often raises concerns of touching or overlapping active region of die metallization or wire size issue during performing monometallic ball or wedge bond.



Comparing other Military Specification requirements.

- MIL-PRF-19500 prohibits the use of bi-metallic bonds unless allowed by the slash sheet. If bimetallic bonds are used, special requirements apply.
 - Any bi-metallic (e.g. gold-aluminum) interface at the die shall be baked for 1 hour at +300°C in either an air or inert atmosphere prior to the performance of the first wire bond strength testing with a minimum sample size of 11 wires, c = 0.
- MIL-PRF-38534 does not prohibit bi-metallic bonds in space grade parts.
- MIL-PRF-38535 classes M, Q, and N (class level B) allows bi-metallic.
- MIL-PRF-38535 class V (class level S) does not allow bi-metallic.
 - Class P SMDs have exceptions gold internal lead wire to aluminum bond pads on a case by case basis.

Industry Trends and Best Practices:

- As technology evolves and industry standards progress, there is a growing recognition of the benefits of bi-metallic bonds in enhancing reliability and performance in microcircuit devices. Aligning MIL-PRF-38535 classes V and P (class level S) specifications with industry trends and best practices promotes interoperability and facilitates technology advancement across the spectrum of device classes.

ATTACHMENT # 2

Feedback on this EP study was provided by 3 device manufacturers and 3 OEM / users. Comments received to this Engineering Practice Study are summarized herein.

OEM / User Feedback:

Program Standards on Bimetallic Wire Bonding.

- Program standards limit the use of bimetallic wire bonding.
 - Should be avoided if possible.
 - Requires documented justification and risk mitigations to be submitted for review and approval consideration.

Technical Concerns at the Wire Bond interface

The following issues are key concerns with Au-Al wire bonds:

- Formation of brittle intermetallic compounds and voids
- Increasing electrical resistance over time (aging effects)
- Risk of wire bond failure due to voiding, leading to separation and catastrophic failure chip packaging.
 - Au5Al2 (White Plague)
 - AuAl2 (Purple Plague) over a long-term aging.

Considerations for Allowing Bimetallic Bonds

- If the manufacturer identifies the component as having bimetallic bonds, risk can be mitigated.
- If the product meets all performance requirements, intermetallic bonds may be allowed.

Device Manufacturer Feedback:

Reliability of Au-Al Bonds

- Au to Al bond pads have demonstrated reliability if:
 - Proper SPC controls are followed.
 - Accelerated aging sampling is conducted.
- Primary Concern: Improper package sealing leading to moisture ingress and bond degradation
 - Properly sealed or encapsulated products typically do not develop these issues over time.

Environmental & Moisture Control for non-hermetic space level devices

- For Class Y/P (non-hermetic):
 - Moisture control measures must be in place (e.g., bake-outs, desiccant storage, MSL bagging).

Comparison of Au vs. Al Wire Bonds

- Au wire is easier to work with than Al wire.
- Au wire has less potential for bond cracking that would expand over time and temperature cycles. This would increase product reliability for Au to Al bonds over Al to Al bonds.

Qualification Data & Material Selection

- Qualification data is available for manufacturers to assess reliability
- If an intermetallic bond affects a specific use case then the customer can procure the correct bond material. It could significantly reduce costs for the manufacturer and customer.

Recommended Testing & Validation

- Accelerated aging sampling (e.g. the 300°C, 1 hour bake per TM 2023, 3.2.1.3). Use extended temp cycling with wire pull testing as part of a PIDTP characterization but not needed as part of lot screening nor for QCI testing unless the wire bonding process has changed
- The example tests will be adequate validation.
 - Thermal Cycling MIL-STD-883, TM1010 (sample size 22)
 - Bond strength TM 2011 Cond D and Ball Shear JESD22-B116 (sample size 22)
 - Long term storage (sample size 22)
 - Bake (sample size 1)

ATTACHMENT # 2 - Continued

DLA Feedback:

Rationale for Conducting the EP Study

- DLA has received requests from manufacturers to permit the use of gold (Au) wire bonding to aluminum (Al) bond pads, prompting this engineering practice (EP) study. A primary concern is long-term aging effects associated with intermetallic growth as noted by various programs that currently restrict bi-metallic wire bonds.
- This EP study was conducted to evaluate the impact of these restrictions on MIL-PRF-38535 class level S stock classes by gathering industry feedback.

Impact of Current Monometallic Bonding Restrictions

- Due to the current monometallic bonding requirement, DLA has had to reject numerous new devices for Class V qualification under the Qualified Manufacturers List (QML) program.
- This restrictions limits manufacturers' flexibility in device design and qualification.
- DLA aims to determine whether we can move forward with maintaining the existing monometallic restrictions and establish additional qualification criteria to allow Au-Al wire bonds on a case-by-case basis.

Change Management

- Managing a change of this nature would require further discussion on how to document and notify stakeholders when Au-Al bonding is qualified.