Automotive Electronics Council
Component Technical Committee

AEC - Q006 - REV-

QUALIFICATION REQUIREMENTS FOR COMPONENTS USING COPPER (Cu) WIRE INTERCONNECTIONS

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Acknowledgment

Any document involving a complex technology brings together experience and skills from many sources. The Automotive Electronics Council would especially like to recognize the following significant contributors to the development of this document:

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QUALIFICATION REQUIREMENTS FOR COMPONENTS USING COPPER (Cu) WIRE INTERCONNECTIONS

1. SCOPE

This document contains a set of tests and defines the minimum requirements for qualification of copper (Cu) wire interconnections for components to be used in any automotive electronics application. While the set of tests highlighted here are replicated in AEC-Q100/Q101, this document details any different test conditions and/or durations plus the activity around these tests that are unique requirements for ensuring Cu wire reliability. Use of this document does not relieve the supplier of their responsibility to meet their own company's internal qualification program. In this document, "user" is defined as all customers using a component qualified per this specification. The user is responsible to confirm and validate all qualification data that substantiates conformance to this document.

If a supplier has already qualified Cu wire and is in production with no Cu wire related issues, the supplier does not have to requalify those approved components again per this document.

1.1 Purpose

The purpose of this specification is to determine that a component is capable of passing the specified stress tests and thus can be expected to give a certain level of quality/reliability in the application.

1.2 Reference Documents

Current revision of the referenced documents will be in effect at the date of agreement to the qualification plan. Subsequent qualification plans will automatically use updated revisions of these referenced documents.

1.2.1 Automotive

AEC-Q100 Failure Mechanism Based Stress Test Qualification for Integrated Circuits
AEC-Q101 Failure Mechanism Based Stress Test Qualification for Discrete Semiconductors in Automotive Applications

1.2.2 JEDEC

JESD22 Reliability Test Methods
JESD22-A104 Temperature Cycling (TC)
JESD22-A110 Highly Accelerated Stress Test (HAST)
JESD22-A101 Temperature Humidity Bias (THB) / High Humidity High Temperature Reverse Bias (H3TRB)
JESD22-A105 Power Temperature Cycle (PTC)
JESD22-A103 High Temperature Storage Life (HTSL) / High Temperature Gate Bias (HTGB)
J-STD-035 Acoustic Microscopy for Non-Hermetic Encapsulated Electronic Components
J-STD-020 Moisture/Reflow Sensitivity Classification for Nonhermetic Surface Mount Devices

1.2.3 Military

MIL-STD-750, Method 1037 Intermittent Operation Life (IOL)
MIL-STD-750, Method 1038 (condition A) High Temperature Reverse Bias (HTRB)

2. EQUIPMENT

Not applicable (see referenced documents)

3. DATA SUBMISSION

3.1 Certificate of Design and Construction

For qualification of components with Cu wire, a Certificate of Design and Construction per AEC-Q100/Q101 is required to determine whether available generic data can apply to the part in question for one or more of the required tests in this document.

If applicable, supplier must document the definition of Cu wire product or technology family. This document should explain the selection of family (worst-case) test vehicle(s). In the following list, critical product, construction and material items for defining Cu wire product or technology families are given:

Relevant items in Certificate of Design and Construction (referenced Q100 Appendix 2 item number shown in parentheses below):

- (4) Wafer/Die Fab Location and process ID
- (6) Assembly Location and process ID
- (10a-c) Die Dimensions
- (11c-d) Die Top Metallization and Thickness (including plating if applicable)
- (12b) Die Passivation Material
- (13) Die Overcoating Material
- (17a) Die Attach Material
- (19) Mold Compound Type (Material)
- (20a-b) Wire Bond Material & Diameter
- Either (21a-h) Leadframe material, plating and dimensions
  Or (22a-b) Substrate material and thickness

3.2 Test Results

The following data is to be submitted to the user for approval on request:

- Cu wire stress test qualification results
- Wire pull/ball shear – mean, min, max, standard deviation
- CSAM images before/after stressing
- Electrical/ATE functional/parametric test results before/after stress tests
- Cross-sections of ball/wedge bonds (as needed per Section 5)

4. QUALIFICATION TESTS

The required set of qualification stresses, test conditions and test durations are shown in the following sections, with an enhanced qualification flow described in Table 2.

Qualification of Cu wire components to standard AEC-Q100/Q101 requirements for temperature cycling can be conducted if board level stress test (Section 4.5) was performed with no issues or fails observed. Otherwise, the supplier must perform the enhanced qualification flow described in Table 2 on a family/technology specific component at a minimum.

If a supplier has already qualified Cu wire and is in production with no Cu wire related issues, the supplier does not have to requalify those approved components again per this document.

4.1 Temperature Cycling (TC)

This test highlights the differences in the coefficient of thermal expansion of package materials with Cu along with the increased hardness of Cu with respect to gold (Au).

Perform per the requirements in AEC-Q100/Q101.

4.2 Biased Humidity (HAST/THB/H3TRB)

This test can exacerbate corrosion along the Cu/bond pad intermetallic compound (IMC) interfaces.

Perform per the requirements in AEC-Q100/Q101.

4.3 Power Temperature Cycle (PTC) / Intermittent Operation Life (IOL)

This test can accelerate wearout by the combination of current/voltage and temperature.

Perform per the requirements in AEC-Q100/Q101.

4.4 High Temperature Storage Life (HTSL) / High Temperature Gate Bias (HTGB) / High Temperature Reverse Bias (HTRB)

This test can accelerate IMC growth along the Cu/Aluminum (Al) interface to yield an open bond failure. It can also degrade the mechanical performance of the stitch bond. This is especially important for high temperature applications.

Perform per the requirements in AEC-Q100/Q101.

4.5 Board Level Stress Test

Performance of this board-level temperature cycling test along with the test conditions, sample sizes and bill of materials to be used is to be agreed to between the user and supplier and justified by data.

5. ANALYTICAL TESTS

5.1 Delamination/CSAM

Delamination of the mold compound over the Cu ball or stitch bond could lead to joint fatigue failure at either weld joint. The delamination criteria for various stages of qualification testing are shown in Table 1.

Table 1: Delamination Criteria

	Read Point	Mold Compound Delamination acceptance criteria	Electrical
Qualification Requirements	T_0	No delamination at first (ball) or second (stitch/wedge) bonds unless otherwise agreed between supplier and user. (1)	All components passing production test
	Post MSL PC	No delamination at first (ball) or second (stitch/wedge) bonds unless otherwise agreed between supplier and user. (1)	All components passing production test
	1X AEC grade X	No delamination at first (ball) bond. If any second (stitch/wedge) bond delamination found – no heel cracks or any other Cu-related fail mechanisms allowed.	All components passing production test
	2X AEC grade X (TC included if no BLR performed)	Evaluate the severity of any bond delamination found per Sections 5.2 and 5.3. (2)	All components passing production test (3)
Minimum CSAM samples size: EITHER the same 11 components per lot through each readpoint (preferable) OR 22 random components per lot at each readpoint.			

Notes:

(1) Agreement between the supplier and user would be achieved via the exchange of data that demonstrates that the form of delamination seen is not an issue for this part based on supporting data (field, monitor, in-process, etc.).
(2) Method of evaluation to be determined by the user and supplier.
(3) At 2x TC read point, passing production test means zero systematic Cu wire related issues. For example, if a failure was found to be related to solder ball or substrate, that is not considered a valid Cu wire failure.

5.2 Wire Bond Integrity

The tests described below and where they are performed are a good gauge of the bond strength and weld formation of the ball and stitch bonds. They are done to demonstrate no reliability risk. The location of the hook for bond pull should be over the contact of interest (i.e., over the ball and over the stitch/wedge).

- Ball shear – ball bond area versus shear force (pre-packaged)
- Wedge bond wire pull (pre-packaged)
- Perform wire pull/ ball shear on first bond and wire pull for stitch bond (post packaged)
- Pad cratering test (pre-packaged)

Wire pull / ball shear is performed after stress testing and decapsulation. A recommended process flow is described below:

1. Select components per the sample size specified in AEC-Q100/Q101 for wire pull and shear. Selecting worst-case components based on CSAM is desirable.

2. Carefully decapsulate these components so as to not damage or adversely affect the wire bonds but enough to be able to reliably conduct wire pulls and/or bond shears.

3. The wire pull hook should be situated over the wedge bond for stitch bond pull and over the ball for ball bond pull. Stitch bond pull force results after stress testing may not be a reliable gauge of bond quality, as the act of pulling a wedge might not be repeatable and/or reproducible.

4. Compare these results with production data (i.e., before mold) to see if there is a level of degradation in the distribution of the data that could reasonably point to a potential reliability issue. If there are positively biased wires required in the test, ensure that they are included in this analysis, as they are thought to be more susceptible to corrosion.

5. In conjunction with pull/shear after decapsulation, a thorough inspection of the wedge bonds should take place to look for heel cracks or precursors for failure.

For temperature cycling, pulls and shears at corner locations of the die/package are preferable. For moisture stressing, selecting random balls/stitches is acceptable (uniform moisture penetration) but ensure that both biased and unbiased pins are selected. Determination of which wires per device undergo ball shear, ball pull or stitch pull is left to the supplier to determine as long as the intent of inspecting all types of bonds is adequately addressed.

5.3 Cross-sectioning Inspection

For initial supplier qualification of a new die/package (interaction) family/technology, components from the CSAM after TC stressing showing both no delamination and delamination over a bond(s) are to be used for cross-sectioning. The sample sizes, test conditions and acceptance criteria are specified in the overall process qualification flow shown in Table 2.

Criteria of examination:

- Ball bond area
  - Amount and distribution of intermetallic - an alternative planar analysis method to evaluate ball bond IMC formation is also acceptable
  - Crack initiation/propagation
  - Corrosion after 1x

- Wedge bond area
  - Amount of contact
  - Wire angle to wedge
  - Crack initiation/propagation
  - Corrosion after 1x
  - Intermetallics formed in the bond area

6. COMPONENT CHANGES

6.1 Qualification Test Requirements for Cu Wire Changes

The method of qualification of changes to already qualified and released components is outside the scope of this document. For those cases, AEC-Q100/Q101 is applicable and the qualification plan shall be based on an assessment of the tests needed for changes per Table 3 of AEC-Q100/Q101 and the relevant fail mechanisms, risk factors and best practices found in Appendix 1 of this document. If degradation models have been developed that can be technically justified via internal and external data to support the equivalent robustness of material and design changes to already-qualified Cu wire parts, this can be used with customer approval to then be allowed to perform AEC-Q100/Q101 testing. If there is limited knowledge or data on changes to already-qualified Cu wire parts, relevant tests should be performed per Q006 Table 2 conditions.

7. QUALIFICATION REQUIREMENTS FOR Cu WIRE COMPONENTS

The table below describes the individual steps required in a qualification flow for Cu wire components and the sample sizes required for each stress test.

The qualification can be performed on a technology basis (define technology family for the purpose of Cu wire). Passage of the technology family allows subsequent components in the family to be qualified using the enhanced requirements below and allow them to be qualified. Subsequent qualification of parts in the same technology but not in the same product family would require performance to this table up to and including sequence #10 only.

Table 2a: Integrated Circuit Qualification Test Requirements based on AEC-Q100

Sequence #	Stress Test / Qualification Step	TC	HAST/THB	PTC	HTSL
1	**Initial sampling**	Sample sizes as required			
2	**CSAM @ T0** (1)	Sample sizes as required			
3	**Preconditioning to MSLx**	3x77	3x77	1x45	---
4	**CSAM after PC** (1)	3x22	3x22	1x22	---
5	**ATE Test**	3x77	3x77	1x45	3x45
6	**Stress 1x**	3x77	3x77	1x45	3x45
7	**CSAM post-1x stress** (1)	3x22	3x22	---	---
8	**ATE Test**	3x77	3x77	1x45	3x45
9a	**Wire pull**	3x3 (4)	3x3 (4)	---	---
9b	**Ball shear**	3x3 (4)	3x3 (4)	---	---
10	**Cross-section**	3x1	3x1	---	3x1
11	**Stress 2x**	3x70 (2)	3x70	1x45	3x44
12	**CSAM post-2x stress** (1)	3x22 (2)	3x22	---	---
13	**ATE Test**	3x70 (2,3)	3x70 (3)	1x45 (3)	3x44 (3)
14a	**Wire pull**	3x2 (2,4)	3x2 (4)	---	---
14b	**Ball shear**	3x2 (2,4)	3x2 (4)	---	---
15	**Cross-section**	3x1 (2)	3x1	---	3x1

Notes:
(1) Either 11 marked or 22 random parts per lot per Table 1 CSAM sample size criteria.
(2) Performed only if board level reliability testing is NOT being performed.
(3) Any failures beyond 1X must directly relate to the Cu wire bonding system for them to count as a legitimate failure requiring further evaluation (i.e., the projected lifetime of failure, effect of fail mode on product lifetime, corrective/preventive action). The method of approval is determined between the user and supplier.
(4) Pull/shear as many as is possible per the number of wires per device to be qualified up to a maximum of 30 wires/balls from the total sample size specified.

Table 2b: Discrete Qualification Test Requirements based on AEC-Q101

Sequence #	Stress Test / Qualification Step	TC	HAST/H3TRB	IOL	HTRB/HTGB
1	**Initial sampling**	Sample sizes as required			
2	**CSAM @ T0** (1)	Sample sizes as required			
3	**Preconditioning to MSLx**	3x77	3x77	3x77	---
4	**CSAM after PC** (1)	3x22	3x22	3x22	---
5	**ATE Test**	3x77	3x77	3x77	3x77
6	**Stress 1x**	3x77	3x77	3x77	3x77
7	**CSAM post-1x stress** (1)	3x22	3x22	---	---
8	**ATE Test**	3x77	3x77	3x77	3x77
9a	**Wire pull**	3x3 (4)	3x3 (4)	---	---
9b	**Ball shear**	3x3 (4)	3x3 (4)	---	---
10	**Cross-section**	3x1	3x1	---	3x1
11	**Stress 2x**	3x70 (2)	3x70	3x77	3x76
12	**CSAM post-2x stress** (1)	3x22 (2)	3x22	---	---
13	**ATE Test**	3x70 (2,3)	3x70 (3)	3x77 (3)	3x76 (3)
14a	**Wire pull**	3x2 (2,4)	3x2 (4)	---	---
14b	**Ball shear**	3x2 (2,4)	3x2 (4)	---	---
15	**Cross-section**	3x1 (2)	3x1	---	3x1

Notes:

(1) Either 11 marked or 22 random parts per lot per Table 1 CSAM sample size criteria.
(2) Performed only if board level reliability testing is NOT being performed.
(3) Any failures beyond 1X must directly relate to the Cu wire bonding system for them to count as a legitimate failure requiring further evaluation (i.e., the projected lifetime of failure, effect of fail mode on product lifetime, corrective/preventive action). The method of approval is determined between the user and supplier.
(4) Pull/shear as many as is possible per the number of wires per device to be qualified up to a maximum of 30 wires/balls from the total sample size specified.

APPENDIX 1: Cu Wire Process and Technology Characterization Guideline

This appendix is meant to be used as a guideline for users of components assembled using Cu wire for the internal interconnects. This guideline is a broad outline of generic items and issues suppliers should address to ensure a reliable Cu wire process in production.

This guideline is meant to illustrate the technical items that need discussion between supplier and user to determine the level of competence in the supplier's development process for Cu wire production. This discussion can involve data from design of experiments, stress tests, historical data, models, etc.

A.1 Failure Mechanisms Related to Copper Wire and Causes/Risk Factors:

- Chipout under ball bond (AEC Q100-001)
  - The pad and underlying structures have higher risk of damage/cracking due to the extra ball bonding force required for Cu wire
  - Bonding over layered active area circuitry
  - Thin passivation layer under bond pad
- Corrosion along Cu/Al IMC interface
  - Trace contaminants/additives in mold compound in presence of moisture
- Insufficient Cu/Al IMC
  - Al bondpad splash from overbonding force
  - Poorly optimized bonding parameters for bonding temperature/frequency/force during thermosonic bonding
  - Oxidation of free air ball during ball bonding
- Crack at wedge heel
  - Delamination at/near the lead tip where wedge located
    - Adequate mold compound cure
    - Mold lock techniques
  - Large CTE mismatch among package materials
  - Mismatch of material properties (e.g., Tg, CTE, elastic modulus) of component and with customer circuit boards
- Wire neck severance
  - Die/mold compound delamination near/at the ball bond

A.2 Best Practices:

- Inert environment around Cu wire
  - During wire storage
  - During free air ball formation
  - (Pd) Plated Cu wire
- Tighter controls/limits for wire pull/shear metrics
  - USL/UCL and LSL/LCL
  - Ball shear and wire pull near/over stitch
  - Production monitor using unmolded parts
  - Pull/shear after stress testing and careful decapsulation
- Capillary
  - More frequent replacement/maintenance
  - Designed specifically for Cu wire
- Thermosonic bonding
  - Tighter parameters for frequency, temperature, force
  - Reliability data collection at bond recipe corners of Force and Frequency
- Mold Compound Material Requirements
  - Sufficiently high pH (generally greater than 5)
  - Cl extracted content (generally less than 15ppm)

- Safe Launch (i.e., initial production period) period for new Qualification and Changes
    - Sample first lots for reliability test
- Bond Pad Construction including active circuits under pad if applicable
    - Selecting the most sensitive bond pad known for analysis
- Ball Bond: IMC contact area after wire bonding
    - Quantify smallest contact area below which there would be a bonding problem
- Wedge Bond: delamination response after TC
    - Quantify the largest amount of delamination change allowed

Revision History

Rev #	Date of change	Brief summary listing affected sections
-	June 8, 2015	Initial Release.