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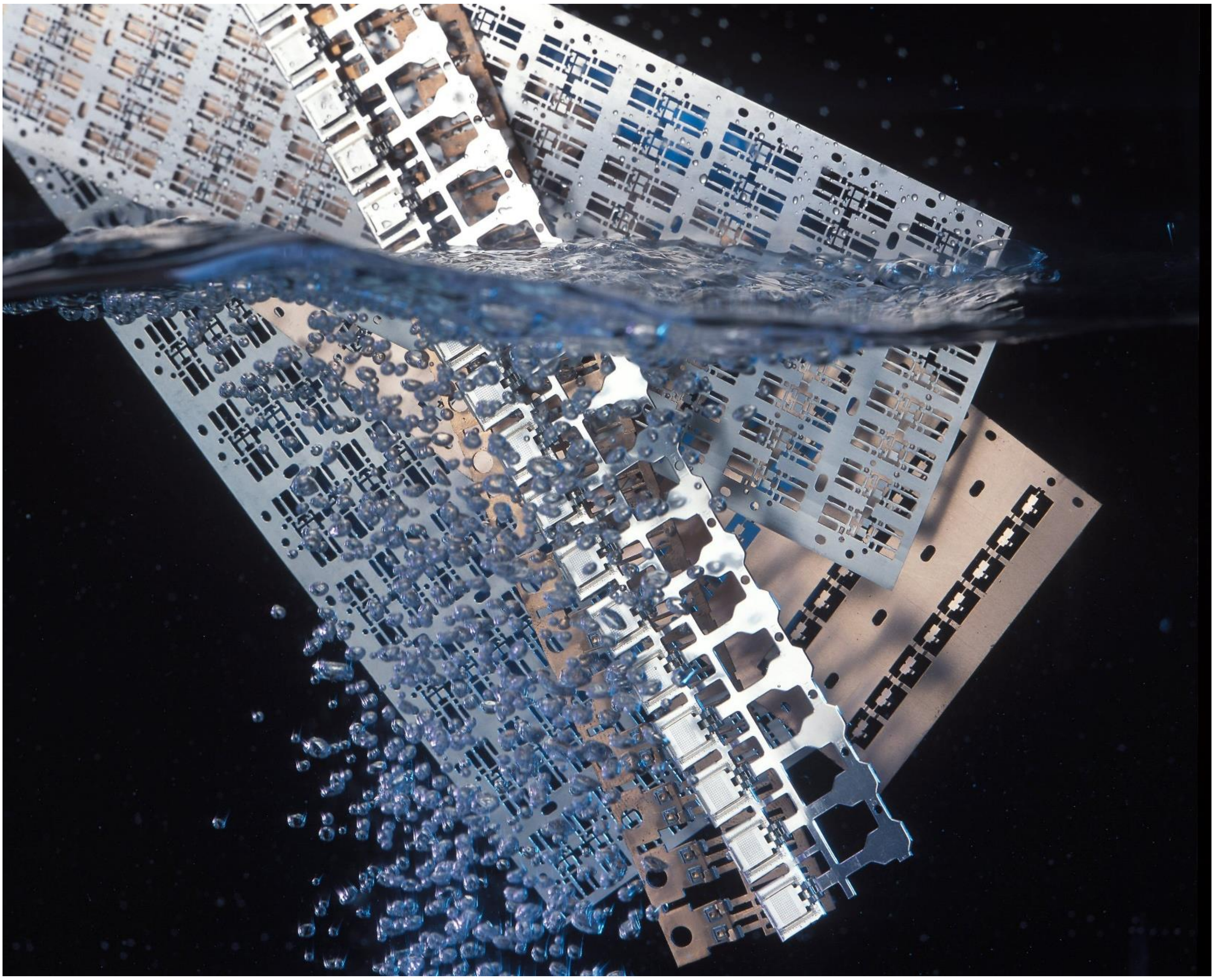
Impact of Cleaning Technology on Discrete Packaging - The Difference in Wire Bonding Yield



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ZESTRON
High Precision Cleaning

Impact of Cleaning Technology on Discrete Packaging – The Difference in Wire Bonding Yield

Lead frame packages are commonly used in semiconductor package fabrication, where interconnections between the integrated circuits (IC) and the metal leads are typically established through die attach and wire bonding processes. Standard materials like epoxies, adhesives, or solder pastes are most often used in the die attach process. However, it is critical to remove any flux residues left behind after soldering before proceeding with wire bonding and moulding to ensure maximum yield in packages that use solder paste for die attachment. One of the most widely used cleaning agents to remove flux residues is isopropyl alcohol (IPA). While IPA is commonly used as a general cleaner in the electronics industry, it is not the most effective solution for flux removal.

Semiconductor package manufacturers produce millions of units daily and therefore, a small improvement in the wire bonding yield can significantly impact production efficiency and the overall product costs.

One such OEM was producing lead frame packages and using an IPA (isopropyl alcohol) in the ultrasonic cleaning process. However, their process resulted in a wire bonding yield of only 98%, measured after the moulding and deflashing processes. This indicated significant motivation to improve the cleaning process and the wire bonding yield.

A Design of Experiment (DOE) was developed to assess alternative cleaning agents and process equipment, aiming to optimize the cleaning process and to be evaluated based on the improvement in wire bonding yield. Process qualification was conducted through a pull test according to the MIL-STD-883E method 2011.7. Throughout the DOE process iterations, process improvements were identified through visual inspection, pull and shear testing as well as overall yield measurement from the wire bonding process.

Introduction

This study features a global industry-leading OEM that manufactures discrete semiconductors and passive electronic components. Their products serve a wide range of applications, including industrial, communications, transportation, consumer, medical, and defence sectors emphasizing consumer products, mobility, and sustainability applications.

Lead frame packages are key products for this OEM, comprising components like diodes, rectifiers, discrete thyristors, ICs (QFN, QFP, LGA), MOSFETs (DPAK, MLP, SO series), and power supplies (Direct FET). In these packages, the interconnections between an integrated circuit and the metal leads are typically established through die attach and wire bonding processes. In the final stage, the lead frame is moulded in a plastic mould compound.

The OEM's current wire bonding process included an additional Ball Stitch on Ball (BSOB), using the 1.2 mil (30.5μm) Gold (Au) wire bonding. The process involves two steps – one is to form a stud ball on the lead pad and another on standard bonding. See Figure 1 for reference.

Figure 1. Current Wire Bond Process (BSOB)

Given the high volume – million units of semiconductor devices manufactured by this OEM per day, it is necessary for the company to review their production and quality processes to identify opportunities for both process and yield improvements. With the developed test plan, the company focuses on improvement in the wire bonding yield. Additionally, they also aimed to explore the possibility of eliminating BSOB which could improve the process efficiency and reduce costs.

Background

Before this study, the OEM applied an ultrasonic cleaning process using IPA as the cleaning agent. The cleaning process involved a wash cycle with a standard four-tank immersion dip over a 15-minute cycle time. Their current wire bonding process yield was 98% as measured after the moulding and deflashing process.

Wire bonds can fail in numerous ways. The examples and potential causes for each type of failure are outlined in Table 1.

In the standard gold wire bonding process, the typical approach is to ball bond to the chip and then stitch bond to the lead frame. This requires very tight control during the process to enhance proper looping characteristics and eliminate sagging.

The BSOB process usually increases the gold wire consumption and slows down the overall bonding process

Wire Bond Failures Wire Bond	
Failure	**Possible Causes**
Lifted Ball Bond (LBB) & Non-Stick on Pad (NSOP)	▪ Contamination on bond pad ▪ Incorrect wire bond parameters setting ▪ Bond pad corrosion ▪ Excessive bond power ▪ Improper positioning on the bond pad (misalignment)
Ball Bond Neck Break	▪ Incorrect wire bond parameters setting ▪ Incorrect wire looping
Cratering	▪ High ultrasonic energy (bond power) ▪ Incorrect wire bond parameters setting
Peeling	▪ Incorrect wire bond parameters setting ▪ Tool quality degradation

Table 1. Wire Bond Failures

compared to the standard method, which also increases the risk of damaging the bare die.

For this OEM, the wire bond yield was affected by material losses including lead frames, gold wire and chip attachment which led to significantly higher overall process costs. Eliminating the BSOB process would reduce costs and improve both process safety and productivity or UPH (Units per Hour). The OEM believed that the key to achieving this is through the development and implementation of an improved cleaning process that once verified, could be qualified with their customer base.

Recognizing opportunities for both quality improvement and cost savings, the OEM sought to collaborate with ZESTRON, a leader in high-precision cleaning products for SMT and semiconductor applications, to develop a test plan to assess the effectiveness and efficiency of their current wire bonding process as well as identify opportunities for process improvement. The primary objectives of the test plan were:

- To improve the cleaning process before wire bonding to increase the yield rate.
- To eliminate the BSOB process to reduce overall process costs and increase productivity.

For the test plan, the OEM chose to evaluate an alternative solvent cleaning agent, labelled as an ORGANIC SOLVENT, against their current IPA solution, using the existing ultrasonic cleaning system. Additionally, the OEM recognized that ultrasonic energy can negatively affect solder joints and chip surfaces which can lead to solder cracks and peeling. Thus, they also decided to assess an alternative cleaning method using the centrifugal cleaning system. Cleaning trials with the centrifugal cleaning system were conducted using only the ORGANIC SOLVENT.

Design of Experiment (DOE)

The Design of Experiment (DOE) was initially structured around three cleaning process scenarios including:

- First Scenario
  - Ultrasonic cleaning process with visual inspection conducted at the ZESTRON Technical Centre.
- Second Scenario
  - Centrifugal cleaning process conducted at the equipment supplier facility.
- Third Scenario
  - Ultrasonic cleaning process conducted at the OEM site.

The test vehicle used in this study was an OEM-supplied lead frame that was reflowed after die and clip attach using a

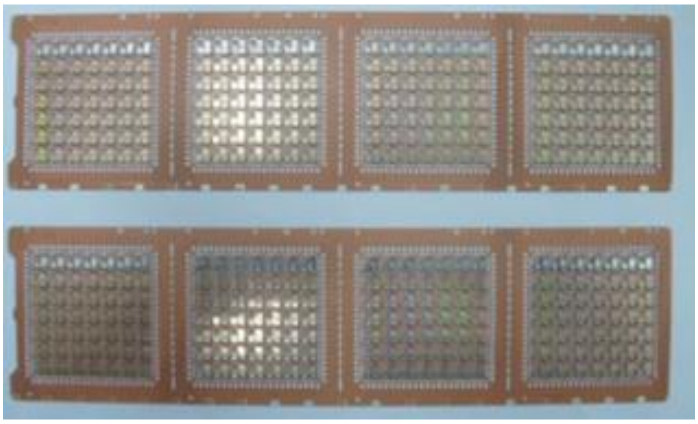

Figure 2. OEM Test Vehicle

high-lead No Clean (ORL0) solder paste. See Figure 2 for reference.

In all three scenarios, the alternate cleaning agent, ORGANIC SOLVENT, was used for the cleaning trials. All wire bond evaluations were performed by the OEM at their facility.

The effectiveness of the cleaning process was evaluated through visual inspection as well as wire pull and shear tests utilizing the following test methods:

[1] Visual Inspection: MIL-STD-883E Method 2010 & 2017

- Enables confirmation of the proper formation of ball and wedge bonds.
- Verifies that the bonds are correctly positioned relative to the bond pads and lead pads of the lead frame substrate.

[2] Pull Test: MIL-STD-883 Method 2011 (destructive) and Method 2023 (non-destructive)

- Measures the strength and failure mode of the wire bond; with typical failure expected at the neck of the ball bond as outlined in Figure 3.
- The minimum pull force for the destructive pull test per MIL-STD-883 Method 2011.7 is outlined in Figure 4.

The wire bonding results were classified through the wire pull test analysis as referenced by Figure 5 and Table 2.

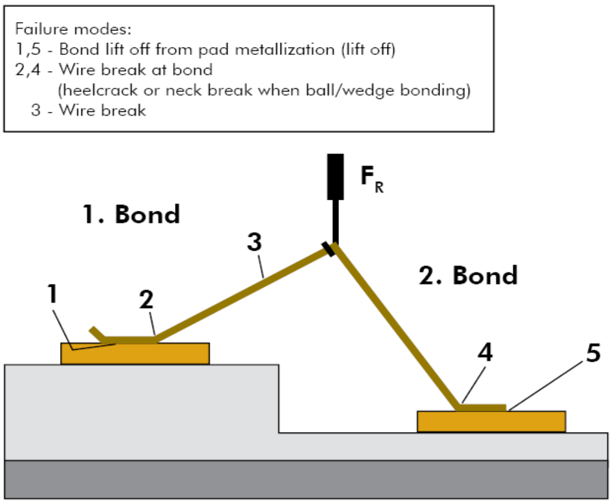

Figure 3. Pull Test Method

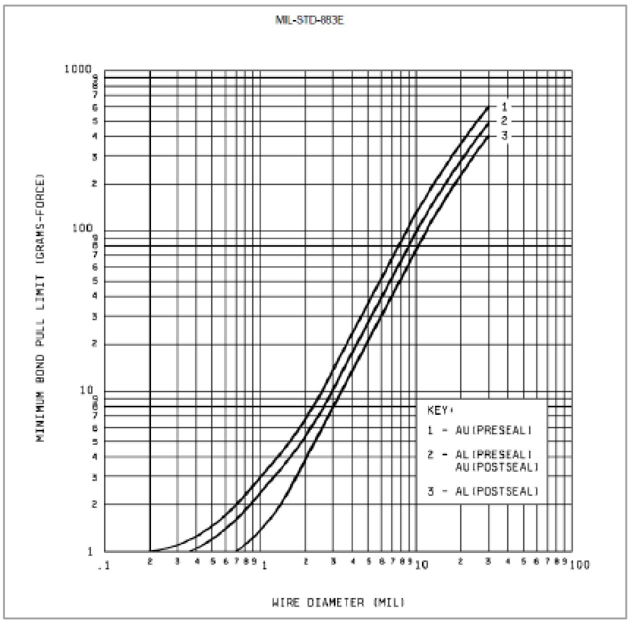

Figure 4. Minimum Pull Force (MIL-STD-883G)

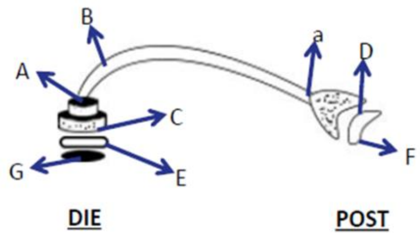

Figure 5. Wire Bond Failure Modes

Wire Pull Test Analysis	
Failure Point	Failure Description
A	Wire break at neck-down point from die
a	Wire break at neck-down point from substrate post
B	Wire break at point other than neck-down
C	Failure in bond at die
D	Failure in bond at substrate, package post
E	Lifted metallization from die
F	Lifted metallization from substrate or package post
G	Fracture of die

Table 2: Wire Bond Failure Description

[3] Shear Test: EIA/JESD22-B116

- Assesses the quality of the ball bond as the ball shear data reflects the intermetallic formation and its coverage on the bonds. See Figure 6 for reference.

The test data generated using the ORGANIC SOLVENT cleaning agent in both the ultrasonic and centrifugal cleaning equipment was compared to the OEM's existing data using their current cleaning process (ultrasonic and IPA).

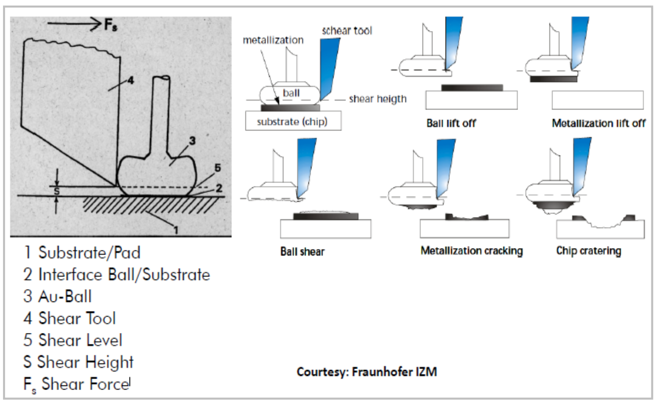

Figure 6. Ball Shear Test Process Description

Methodology

A. First Scenario

The OEM prepared the die and clip lead frames attached with high lead No-Clean solder paste and sent them to ZESTRON for cleaning. The elapsed time between assembly and cleaning was approximately seven (7) days.

Four (4) cleaning trials were conducted using the ultrasonic process with ORGANIC SOLVENT following the parameters as outlined in Table 3.

For the pull test, the failure point specification was 4 grams, with the preferred failure mode being 'A', 'a' or 'B' (refer to Figure 5). The results showed that all trials were unsatisfactory except for wire numbers 14 and 17, where the failure occurred at mode 'A' and above the 4-gram specification.

The pull test results from the first scenario are summarized in Table 4:

Ultrasonic Cleaner Operating Parameters (Cleaning Agent: Organic Solvent)						Visual Inspection Results
Trial	Cleaning Time	Solvent Temperature	Rinse Agent	Rinse Cycles / Time	Hot Air Drying	
1	12 min.	50°C	DI-water	2 @ 5 min each	10min @ 70°C	++
2	15 min.	55°C	DI-water	2 @ 5 min each	10min @ 70°C	++
3	15 min.	55°C	IPA	1 @ 2 min; 1 @ 20sec	2min @ 70°C	++
4	30 min.	55°C	DI-water	2 @ 5 min each	10min @ 70°C	+
++: Very Good +: Very Minor Residues / Stains 0: Satisfactory -: Unsatisfactory						

Table 3. Ultrasonic Process Operating Parameters

Results of First Scenario:

The visual inspection showed no flux residues on the bond or lead pads. The best results were achieved in Trials 1 and 2 with wash times of 12 minutes and 15 minutes respectively as shown in Figures 7 – 8.

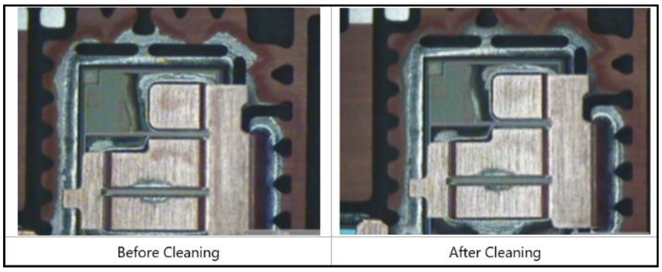

Figure 7: Trial 1 – Visual Inspection Results

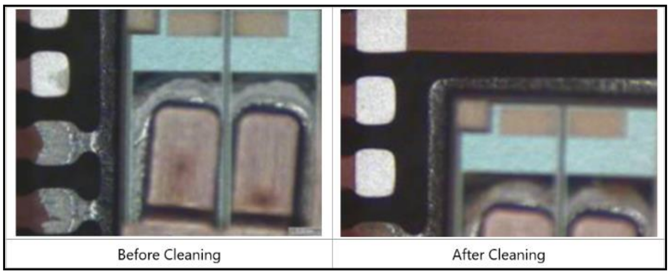

Figure 8: Trial 2 – Visual Inspection Results

Substrates were returned to the OEM for the standard wire bonding process, which involves one ball bond on the bond pad, followed by a stitch bond on the lead pad. The BSOB process was not considered as the objective was to eliminate the process. Wire bond testing was then conducted to compare the cleaned substrates from the four (4) trials with an uncleaned substrate sample as a control.

	Wire Pull Test Results				
Wire Number	Unclean sample	Trial 1	Trial 2	Trial 3	Trial 4
1	2.8D	7.7D	1.3C	4.3D	3.7D
2	4.1D	3.1D	3.3D	2.5D	2.7D
3	2.5D	5.2D	6.6D	1.7D	3.6D
4	3.1D	3.7D	3.1D	3.7D	3.1D
5	2.6D	4.8D	4.1D	2.7D	3.8D
6	2D	1.9D	4.2D	1.8D	2.5D
7	4D	5.5D	2.6D	4.9D	3D
8	5D	5.3D	3D	1.4D	3.8D
9	2.8D	6.3D	3.2D	1.4D	3.9D
10	3D	3.5D	2.7D	0.6D	2.9D
11	5.8D	5.2D	3.5D	2.2D	8.9A
12	11.5D	5.7D	4.5D	2.4D	5.3D
13	3.3D	3.1D	1.2D	1.0D	3.3D
14	6.3A	5.7A	5.8A	6.9A	2.4C
15	1.1D	1.8D	2D	2D	4.0D
16	2.2D	2.2D	4.1D	2.3D	3.4D
17	7.7A	5.5A	7.1A	7.1A	6.1A
A: wire neck C: Die bond off D: LF bond off				Spec: 4g min.	

Table 4. First Scenario Pull Test Results

Based on the results from the first scenario, the authors implemented several process changes for the second scenario trials to improve the wire bond quality results. The changes include reducing the ultrasonic cleaning wash time, minimizing the delay time between soldering and cleaning, and shortening the time between cleaning and bonding. Additionally, they introduced the centrifugal cleaning process at a reduced wash time.

B. Second Scenario

This evaluation was conducted at the equipment supplier facility and included evaluating both ultrasonic and centrifugal cleaning, using ORGANIC SOLVENT for both methods. In these trials, the ultrasonic cleaning time was reduced to 5 minutes. The centrifugal cleaning process was tested with two wash times of 10 minutes and 5 minutes, respectively. Both the centrifugal system washing chamber and cleaning process are shown in Figure 9.

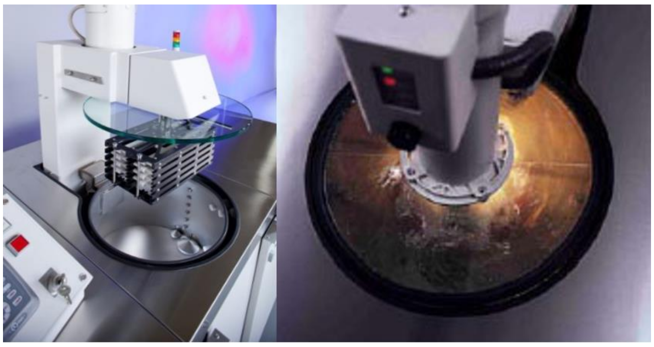

Figure 9. Centrifugal System loading and cleaning process

Cleaning equipment operating parameters are outlined in Table 5.

Cleaning Equipment Operating Parameters (Organic Solvent)				
Equipment Type	Cleaning Time	Solvent Temperature	Rinse Agent	Dry Time / Temperature
Centrifugal 1	10 min.	50°C	DI-water	5 min / 190°C
Centrifugal 2	5 min.	55°C	DI-water	5 min / 190°C
Ultrasonic 1	5 min.	55°C	DI-water	5 min / 190°C
Ultrasonic 2	5 min.	55°C	IPA	Dry

Table 5. Second Scenario Cleaning Equipment Operating Parameters

Results of Second Scenario:
Pull test results for the second scenario cleaning trials are outlined in Table 6.

Wire #	Centrifugal – 1				Centrifugal – 2				Ultrasonic – 1				Ultrasonic – 2			
	Strip 1		Strip 2		Strip 1		Strip 2		Strip 1		Strip 2		Strip 1		Strip 2	
1	4.6	d	5.6	a	3	d	12.3	A	8.5	a	4.1	c	7	a	6.3	a
2	2.2	D	1	d	16.6	A	3.5	d	5.8	a	8.3	a	10.9	a	10.6	a
3	7.9	a	3.5	d	9.2	a	6.8	a	9.9	A	7.9	a	9.7	A	7	a
4	2.5	d	2.2	d	14	A	13.3	A	12.9	A	13.1	A	11.9	A	6.8	a
5	2.2	d	1.9	d	4.8	a	6.7	a	7.5	a	5.3	a	6.7	a	5.5	a
6	3.3	d	1.3	d	8.9	a	5.7	a	7.9	a	7.1	a	9.3	a	6.2	a
7	2.5	d	1.6	d	9.9	a	7.5	a	5.6	a	10.3	a	14.3	a	5.3	a
8	4.8	d	3.2	d	14	a	4.7	a	4.9	a	10.9	a	7	a	3	d
9	5.9	a	7.6	a	13.6	a	5.5	a	5.4	a	5.5	a	6.5	a	6.8	a
10	5	a	6.5	a	11.9	a	8.9	a	14.7	b	6.9	a	9.7	a	6.6	a
11	7.7	a	7	a	8.8	a	15.7	a	15.1	b	7.3	a	11.6	a	10.7	a
12	5.7	a	5.9	a	6.6	a	5.7	a	5.1	a	4.6	a	6.2	a	6.4	a
13	3.5	d	7.4	a	5.3	d	3.6	d	11.7	A	5.4	a	12.9	b	14.2	a
14	6.2	A	7.1	A	6.2	A	6.8	A	6.7	A	6.2	A	5.8	A	7.3	A
15	4.2	a	5.5	a	5.4	a	14.3	A	5.9	a	2.8	d	6.9	a	9.7	a
16	8.4	a	4.8	a	9.5	a	7.5	A	4.8	a	2.5	d	11.2	a	13.6	a
17	6.4	A	5.4	A	6.4	A	6.3	A	8.1	A	5.4	A	6.2	A	6.3	A
Max	8.4		7.6		16.6		15.7		15.1		13.1		14.3		14.2	
Min	2.2		1		3		3.5		4.8		2.5		5.8		3	
Avg	4.88		4.56		9.06		7.93		8.26		6.68		9.05		7.78	
Std Dev	2.03		2.31		3.87		3.72		3.42		2.82		2.71		2.98	

Table 6. Second Scenario Pull Test Results

Overall, the wire pull results showed improvement. The best results were achieved in trials Centrifugal 2 - strip 2, Ultrasonic 1 - strip 1 and Ultrasonic 2 - strip 1. In each of these trials, the cleaning time was 5 minutes.

However, it was observed that the failures occurred only with the short wire bonds. Thus, the authors worked with the OEM to review and optimize the wire bonding parameters, particularly for short wire to improve results in the next testing.

Nonetheless, these results were encouraging enough to proceed with the third scenario trials at the OEM facility. One key advantage of this scenario was that the staging times between soldering and cleaning as well as between cleaning and wire bonding were minimized. Regarding the cleaning process, the OEM decided to conduct the trials with their ultrasonic cleaning process as the centrifugal cleaner was not available at their facility.

C. Third Scenario

This evaluation was conducted at the OEM facility using their ultrasonic cleaner with the ORGANIC SOLVENT. Refer to Table 7 for the ultrasonic cleaner operating parameters.

Ultrasonic Cleaner Operating Parameters (Organic Solvent)				
Leg #	1	2	3	4
Organic Solvent with Ultrasonic (50°C)	5 min.	3 min.	7 min.	5 min.
DI-water Tank	0.5 min.			
DI-water with Ultrasonic	1 min @ room temperature		1 min @ 50°C	
DI-water Tank	1 min			
DI-water Spray	1 min			
Dry with Hot Air	5 - 10min (until dry)			
Sample Size (No. Strips)	3	1	1	1

Table 7. Third Scenario Ultrasonic Cleaner Operating Parameters

Results of Third Scenario:

The wire pull tests were conducted on 5 units from each lead frame (each strip containing 192 units) with each unit including 17 wires for a total of 85 pull tests per Leg. Failures, either below the 4-gram limit or in the incorrect mode are indicated in red. The results for the individual legs are outlined in Tables 8 – 11.

Unit # / Wire #	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5	
1	8.9	a	9.1	a	5.9	a	11.4	A	6.3	a
2	6.4	a	8.3	a	9.4	a	5.2	a	7.4	a
3	7.8	a	10.5	a	10.3	a	7.7	a	7	a
4	7.6	D	12.8	a	6.3	a	9.1	a	7.7	a
5	11.9	a	8.3	a	6.8	a	14.2	A	7.1	a
6	9.1	A	6.5	a	6.1	a	5.3	a	5.5	A
7	7.3	a	7.3	a	8	a	7	a	7.9	a
8	12.8	a	5.5	a	4.9	a	11.8	a	5.6	D
9	6.1	a	6.2	a	5.5	a	7.6	a	8.4	a
10	5.9	a	5.3	a	4.7	a	5.4	a	5	a
11	6.7	A	6.7	a	7.6	A	7.9	A	8.7	A
12	5.4	a	4.6	a	4.1	a	3.9	D	4.9	a
13	3.3	d	4	a	3.9	a	4.2	D	12.2	A
14	6.9	A	7.1	A	5.7	A	6.6	A	6.3	A
15	5.3	a	5.3	a	5.1	a	4.6	a	4	D
16	4.6	a	4.9	a	4.2	a	3.9	a	3.8	a
17	8	A	6.7	A	6.8	A	6.8	A	6.8	A
Max	12.8		12.8		10.3		14.2		12.2	
Min	3.3		4		3.9		3.9		3.8	
Std Dev	2.42		2.26		1.81		2.97		2.02	

Table 8. Third Scenario Pull Test Results Leg 1

Unit # / Wire #	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5	
1	14	A	8.1	a	13.1	A	14.7	B	14.4	a
2	7.6	a	8.3	a	7.3	a	8	a	9.5	a
3	8.6	a	6.8	a	7.9	a	7.8	a	8.6	a
4	7.8	a	9.6	a	8.2	a	13.7	B	7.4	a
5	11.9	a	11.6	a	9.4	a	11.3	a	12.6	a
6	5.8	a	6.7	a	6.7	a	5.9	a	4.7	a
7	10.8	a	5.9	a	7.1	A	6.6	a	5.2	a
8	5.4	a	8.4	a	10.6	A	7.8	a	6.6	a
9	6.2	a	7.5	a	6.9	a	5.9	a	6.6	a
10	7.2	a	4.7	a	5.2	a	4.3	a	6.6	a
11	7.9	A	6.3	a	9.6	A	6.6	a	6.7	a
12	5.9	a	11.6	A	10.1	a	10.1	a	8.5	a
13	6.7	a	4	a	11.6	a	11.5	a	12	A
14	7.8	A	5.5	A	6	A	7	A	6.5	A
15	4	a	4.8	a	5.4	a	9.3	a	4.9	a
16	4.1	a	4.4	a	8.6	a	4.1	a	4.7	a
17	8.8	A	6.3	A	7.5	A	6.6	a	8.5	A
Max	14		11.6		13.1		14.7		14.4	
Min	4		4		5.2		4.1		4.7	
Std Dev	2.64		2.30		2.19		3.06		2.85	

Table 9. Third Scenario Pull Test Results Leg 2

Unit # / Wire #	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5	
1	14.4	A	9.8	a	10.3	a	4.7	a	8.2	a
2	7.5	a	7.6	a	8.3	a	8.3	a	7.7	a
3	8.9	a	10.9	a	4.1	a	10.9	a	6.5	a
4	7	a	6	a	5.7	a	11.5	a	8	a
5	7.7	a	9.4	a	6.6	a	5.5	a	8.6	a
6	11	A	4	a	5.5	a	10.1	a	6.4	a
7	8.6	a	5.2	a	11.9	a	7.5	a	12.3	a
8	10.8	a	6.4	a	8.7	a	7.6	a	7.9	a
9	8	a	5	a	3.4	a	7.9	a	9.2	a
10	5.5	a	5.7	a	4.1	a	6.3	a	5.7	a
11	7.4	A	7.5	a	6.6	A	5.3	a	5.3	a
12	4.4	a	7.5	a	4	a	4	a	12.2	a
13	3.7	a	4.1	a	3.8	a	11	A	3.5	a
14	5.4	A	6.4	A	7.2	A	6.5	A	5.7	A
15	4.5	a	4.8	a	4.3	a	4	a	3.4	a
16	4.6	a	4.3	a	5	a	2.7	a	3.8	a
17	6.6	A	8	A	7.3	A	6.1	A	6.2	A
Max	14.4		10.9		11.9		11.5		12.3	
Min	3.7		4		3.4		2.7		3.4	
Std Dev	2.80		2.07		2.44		2.65		2.61	

Table 10. Third Scenario Pull Test results Leg 3

Unit # / Wire #	Unit 1		Unit 2		Unit 3		Unit 4		Unit 5	
1	9.4	a	13.7	A	2.2	D	12.5	A	11.9	a
2	8.8	a	7	a	7.6	a	6	a	10	A
3	8.4	a	7.3	a	8.9	a	6.4	a	6.5	a
4	13.6	a	12	a	10.6	a	13.6	A	12	a
5	11.4	a	13.2	a	18.5	A	8.7	a	11.7	a
6	11.6	A	4.7	a	6.8	a	5.1	a	5.4	a
7	6.6	a	7.5	a	7.5	a	6.8	a	8.5	a
8	10.5	a	11	a	11.5	A	10.7	a	5.7	a
9	6.7	a	5.2	a	5.4	a	12.7	A	6.6	a
10	4.9	a	8.1	a	11.9	A	6.6	A	6.2	a
11	6.7	A	7.5	a	7.4	A	8.1	A	4.6	a
12	4.2	a	5.4	a	11	a	8.5	a	5.8	a
13	12.5	a	11.4	A	12.6	a	14.7	A	3.8	a
14	5.2	A	6.7	A	6	A	5.8	A	5.9	a
15	5.3	a	4.7	a	5.3	a	4.4	a	3.3	a
16	5.3	a	4.5	a	5.3	a	4.1	a	3.3	a
17	6.4	A	7.6	A	8.6	A	7.7	A	8	A
Max	13.6		13.7		18.5		14.7		12	
Min	4.2		4.5		2.2		4.1		3.3	
Std Dev	2.95		3.05		3.79		3.31		2.90	

Table 11. Third Scenario Pull Test results Leg 4

As shown in Table 9, Leg 2 achieved the best results, with all modes meeting the 4-gram minimum requirement. However, the OEM was also concerned with the potential for failure at mode 'D'. In this mode, an additional ball bond is required for BSOB wire bonding. Given that the standard wire bonding process was followed, if mode 'D' meets the minimum pull test requirement, BSOB can be eliminated on the lead pads.

Once again, Leg 2 yielded the best results, with no failure observed in mode 'D' during the wire pull test. See Table 12 for reference.

Wire Bond Pull Test Results – Failure Analysis				
Leg #	1	2	3	4
Mode D Failure (No. Wires / %)	(6) / 7.06%	(0) / 0%	(0) /0%	(1) / 1.18%
Modes < 4g (No Wires / %)	(5) / 5.88%	(0) / 0%	(7) / 8.24%	(3) / 3.53%
Total Modes Failure (No Wires / %)	(9) / 10.59%	(0) 0%	(7) / 8.24%	(4) / 4.70%

Table 12. Third Scenario – Wire Bond Pull Test Results

For the Ball Shear Test, a minimum value of 20 grams is required for a passing result. Ball Shear Test results are outlined in Table 13.

All shear test values exceeded the 20-gram minimum value, with Leg 2 yielding the best overall results. In this case, the optimum cleaning time was three (3) minutes using the ultrasonic cleaning process.

Unit # / Wire #	Leg 1		Leg 2		Leg 3		Leg 4	
1	47.35	A	44.23	A	42.8	A	43.7	A
2	39.52	A	36.11	A	38.4	A	39.4	A
3	39.03	A	33.53	A	37.3	A	37.5	A
4	41.67	A	36.08	A	35.7	A	40.3	A
5	39.44	A	38.03	A	33.8	A	37.9	A
6	38.41	A	35.48	A	36.3	A	36.8	A
7	38.17	A	32.47	A	39.4	A	38.1	A
8	35.09	A	33.15	A	38.2	A	38.4	A
9	35.89	A	24.34	A	37.2	A	35.4	A
10	42.95	A	36.42	A	40.9	A	41.5	A
11	42.92	A	33.54	A	36.8	A	42.1	A
12	39.67	A	35.64	A	41.2	A	34.4	A
13	42.43	A	38.69	A	34.2	A	32.3	A
14-1	30.09	A	36.05	A	32.9	A	28	A
14-2	27.88	A	26.25	A	31.3	A	29.7	A
15	38.32	A	25.58	A	36.1	A	38.2	A
16	36.62	A	40.51	A	34.4	A	37.9	A
17-1	28.46	A	43.11	A	43.4	A	43.4	A
17-2	34.24	A	29.77	A	28.7	A	29.5	A
Max	47.35		44.23		43.44		43.66	
Min	27.88		24.34		28.65		28.02	
Std Dev	5.07		5.42		3.82		4.57	

Table 13. Third Scenario Ball Shear Test

The Next Step

Based on the positive outcome from the ultrasonic tests results at a three (3) minute cleaning time, the OEM decided to extend the DOE, secure a centrifugal cleaning system and evaluate its performance using the ORGANIC SOLVENT cleaning agent at their facility.

The selected cleaning times were 2.5 minutes, 5 minutes and 7.5 minutes. Each cleaning trial included four (4) cycles: wash, spin-off, rinse, and dry. Additionally, each cycle runs alternatively clockwise and counterclockwise.

Four (4) legs were evaluated using the centrifugal cleaning process. The test parameters established for each cycle are outlined in Table 14.

Centrifugal Cleaning System - Operating Parameters						
	Qty	Cycle	RPM	Sec/Cycle	# Cycles	Temp
Leg 1	4 Strips (784 units)	Wash	100	5	30	55°C
		Spin-off	200	5	1	
		Rinse	100	10	18	35°C
		Dry	300	30	5	190°C
Leg 2	1 Strip (196 units)	Wash	100	5	45	55°C
		Spin-off	200	5	1	
		Rinse	10	10	18	35°C
		Dry	300	30	5	190°C
Leg 3	1 Strip (196 units)	Wash	100	5	15	55°C
		Spin-off	200	5	1	
		Rinse	100	10	18	35°C
		Dry	300	30	5	190°C
Leg 4	2 Strip (392 units)	Wash	100	5	30	55°C
		Spin-off	200	5	1	
		Rinse	100	10	9	35°C
		Dry	300	30	5	190°C

Table 14. MicroCel Centrifugal Cleaner Test Parameters

RESULTS – Centrifugal Cleaner:

Test results from the centrifugal cleaning trials are outlined in Figure 10.

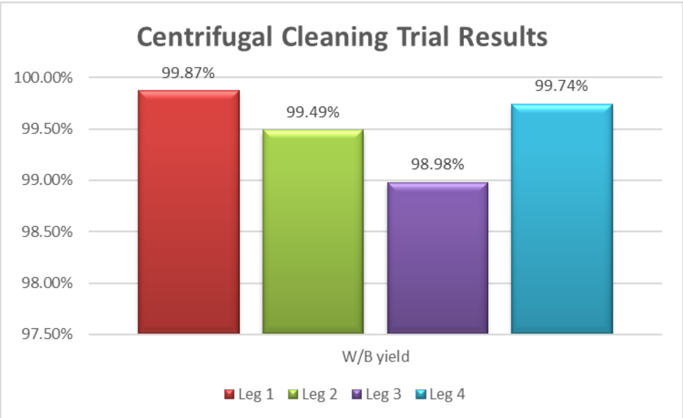

Figure 10. Centrifugal Cleaning Trial Results – OEM Facility

The centrifugal cleaning process showed promising results, with wire bond performance improved beyond the current baseline yield of 98% for all four (4) legs tested.

Based on the results achieved, the OEM decided to implement the centrifugal cleaning process with ORGANIC SOLVENT in their production. This implementation is expected to enhance process efficiency, reduce costs, and avoid potential issues with solder or chip cracks by eliminating the use of ultrasonic cleaning which can negatively affect the solder joint and chip surface. The optimized operating parameters for the centrifugal cleaning process are outlined in Table 15.

Centrifugal Cleaning System Final Operating Parameters					Total Process Time
Cycle	RPM	Sec/Cycle	# Cycles	Temp	
Wash	100	5	30	55°C	~ 25 minutes
Spin-off	200	5	1	--	
Rinse	100	10	18	35°C	
Dry	300	30	5	190°C	

Table 15. Centrifugal Cleaning Process - Optimized Operating Parameters

Figure 11 illustrates the wire bond quality achieved with the centrifugal cleaning process using ORGANIC SOLVENT.

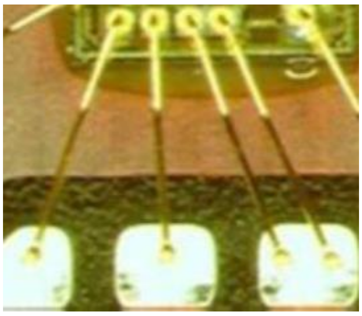

Figure 11. Wire Bond Quality

Conclusion

The results achieved from the DOE demonstrated that both ultrasonic and centrifugal cleaning systems operating with ORGANIC SOLVENT cleaning agents significantly outperformed IPA in terms of wire bond quality.

Following this study, the OEM decided to standardize the centrifugal cleaning process with the use of ORGANIC SOLVENT. By optimizing this process, the OEM achieved several key benefits including:

- Improved wire bond yield averaging above 99%, representing an improvement of more than 1%.
- Eliminated BSOB process which leads to a 50% savings on gold wire costs and a 20% increase in productivity.

This OEM recognized the value of collaborating with an industry leader in electronic high-precision cleaning to conduct a thorough analysis of current processes, reviews of process goals, and development of test plans that would not only address the wire bonding issues but also ultimately exceed the goals for process quality, efficiency improvements and cost savings.

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