



Addressing the Broken Wire Issue during the Assembly Manufacturing of QFN Leadframe Device

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Authors' contributions

This work was carried out in collaboration among the authors. All authors read, reviewed, edited and approved the final manuscript.

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ABSTRACT

The integrity of the assembly wirebond process' 2nd bond poses a big challenge for semiconductor manufacturing of quad-flat no-leads (QFN) devices, particularly on multiple wires on a lead. These devices are vulnerable to induce or obtain broken wire at heel defect. This type of defect is an abnormality in the formation of the stitch, mostly a crack or fracture seen on the facade of the stitch. Normally, it happens when there is too much vibration or transfer of ultrasonic generator (USG) power combined with high bonding force on 2nd bond. In the case of leads with common wires, broken wire at heel could also happen through excessive USG application resulting to transfer of resonance on adjacent wires. This paper presents a better understanding and analysis done to provide an adequate and appropriate solution to broken wire at heel issue.

Keywords: Assembly; broken wire; QFN; semiconductor packaging; USG; wirebond.

1. INTRODUCTION

The quality of wirebond depends on the interconnection between the wire and bond pad and between the wire and the carrier, which in this case a leadframe. Checking for the integrity of 2nd bond is just as important as 1st bond. Worthy to note that with continuing technology development and breakthroughs, challenges in wirebonding process are inevitable [1-5]. The paper focuses on the resolution of broken wire at heel occurrence encountered on both 1 mil Copper (Cu) wire and 2 mil Cu wire (equivalent to 25.4 μm and 50.8 μm , respectively) connected on the same lead finger. Package configuration shows several lead fingers with a triple wire on lead which includes a combination of a single 1 mil wire and double 2 mil wire connected on a common lead. The main challenge when dealing

with such configurations is how to lessen the effect of ultrasonic generator (USG) transfer and vibration during bonding. Fig. 1 shows the reference of lead configuration.

The defect manifestation, which is the broken wire at heel, is an intermittent occurrence seen after wirebond process during the development stage. It is detected through visual inspection using high magnification scope device. Also, the defect manifestation is evident on both 1 mil wire and 2 mil wires as seen in Fig. 2. No commonality observed on failing pins where defect is occurring.

Thorough analysis was performed to identify the potential root-cause, based on the signature of defect. Fig. 3 illustrates the fault-tree diagram done in the analysis.

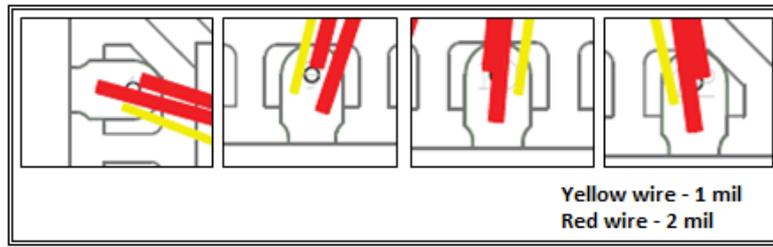


Fig. 1. Multiple wires on lead

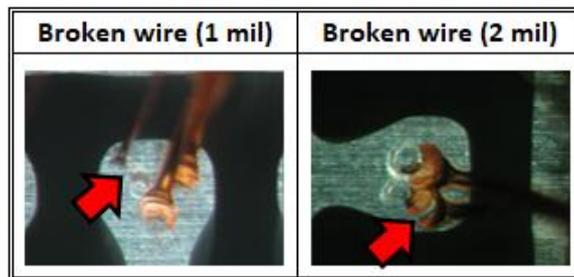


Fig. 2. Defect manifestation

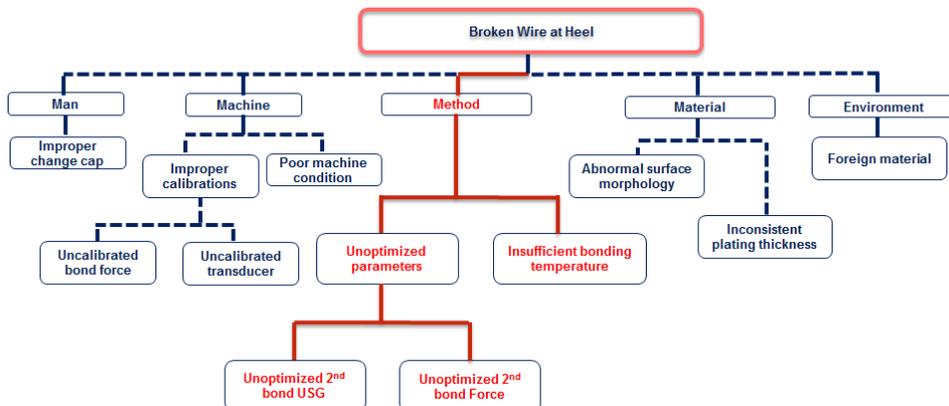


Fig. 3. Fault tree diagram

2. LITERATURE REVIEW

After performing fault isolation and analysis, it is important to understand the theories and principles behind the process to provide an effective and robust solution. First thing to understand is the basic wirebonding principle and parameter application. In theory, there are three basic parameters needed to have an intermetallic connection between two metals. Bond power is the ultra-sonic vibration generated by the transducer to promote adhesion measured in milliamperes (mA). Bond force is the Z-axis movement of the transducer used to determine the amount of compression measured in grams (g). Bond time is the period in which bond force and bond power is applied usually measured in milliseconds (ms). Fig. 4 shows the application of bond parameters.

Another substantial information we need to consider ensuring good intermetallic is the type of bonding used. There are three (3) types of bonding types commonly used in the industry. Ultrasonic bonding is force plus ultrasonic vibration and is most used in wedge-to-wedge bonding for Aluminum (Al) wires. Fig. 5 illustrates the bonding types. Thermosonic bonding is force

plus ultrasonic vibration and Heat. It is the most common type of bonding used widely in semiconductor industry. Lastly, the thermocompression bonding is force plus heat. This type of bonding is not commonly used but has several advantages especially for ball bonding.

Excessive USG parameter application can damage the adjacent bonded wire. The idea is to lessen the USG as much as possible to eliminate the resonance during bonding which induces damage on the previously bonded wire connected on common lead.

Since package configuration consists of 2 wires, the initial sequence was to bond 1 mil wire first then followed by the 2 mil wire due to the complexity of wire layout. Since the 1 mil wire is already bonded, the resulting USG from bonding the 2 mil wire induces damage and crack on 1 mil wire, which is weaker by property compared to 2 mil wire that requires a higher setting of USG parameter to bond. Same scenario was observed for 2 mil wire. The previously bonded wire is unable to take the stress induced by the USG vibration during bonding causing it to break.

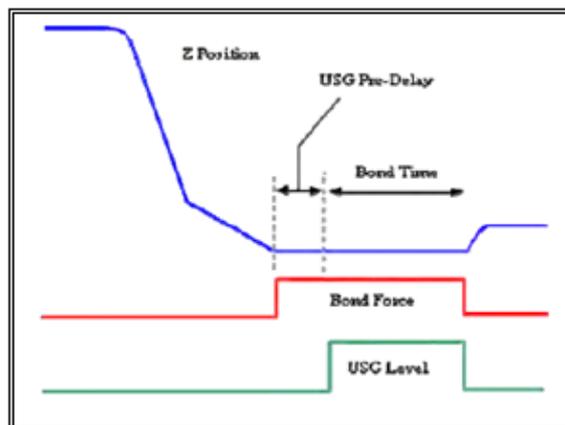


Fig. 4. Bonding parameter application sequence

Ultrasonic	Thermosonic	Thermocompression

Fig. 5. Different types of bonding

3. METHODOLOGY

In this study, the target solution is to eliminate the resonance or vibration induced during bonding to avoid the occurrence of broken wire at heel. Zero-USG approach was evaluated utilizing bond time and bond force parameters only, applying the concept of thermo compression bonding. Two (2) items were considered to resolve the broken wire at heel issue.

3.1 Broken Wire at Heel – 1 mil Wire

To resolve the broken wire at heel issue at 1 mil wire, a change in bonding sequence is required. From bonding the 1 mil wire first, the new sequence will bond the 2 mil wire first, so that it will not be disturbed during bonding of 2 mil wire. Necessary adjustments and optimizations were

also done on looping so that new sequence can be applied.

3.2 Parameter DOE – 2 mil Wire

During parameter screening, the value of USG parameter was set to zero (0). Two factors were considered and optimized during screening. Fig. 6 shows the statistical analysis.

Based on the screening, the team were able to derive workable and optimum parameters using bond time and bond force only. Following the screening process with Low-Mid-High (L-M-H) validation and checking the responses up to 20% from LL settings and 20% from HH to further verify the robustness of the defined parameters. Several units were also bonded to check for the performance in terms of non-stick on lead (NSOL) and short tail occurrence. Table 1 shows the validation table.

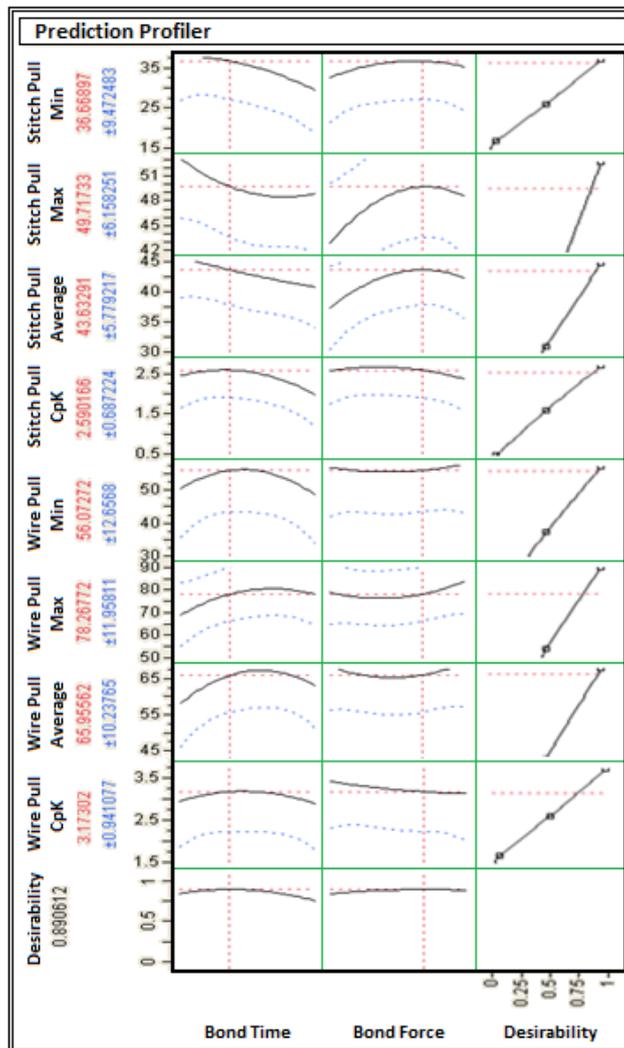


Fig. 6. Statistical analysis

Table 1. L-M-H parameter validation table

Leg	Bond Time (ms)	Bond Force (g)
1	L-20%	L-20%
2	L-10%	L-10%
3	L	L
4	N	N
5	H	H
6	L+10%	L+10%
7	L+20%	L+20%

3.3 Bond Temperature Increase

Since temperature is one of the key ingredients to have an effective thermocompression bonding, it was also considered during the experimentation. To improve the adhesion

strength and quality of the 2nd bond, it is essential to increase the bond temperature as well. Bond temperature was increased by 50 °C to provide a better intermetallic connection and a more stable process.

4. RESULTS AND DISCUSSION

Based on the parameter screening, stitch pull and wire pull test results were able to meet the minimum requirements. No NSOL and short tail assist or error encountered during screening. After arriving at the final parameters, L-M-H validation were performed including responses 20% from LL up to 20% from HH, and all data passed the wire pull and stitch pull response. Table 2 shows the data and results.

Table 2. Wirebonding process validation results

Response	Requirement	-20%	-10%	LL	NN	HH	+10%	+20%
Wire Pull Test	Min > 17 g	NSOL	54.05	54.35	54.31	51.93	55.67	53.02
	Max		82.05	74.56	75.54	73.91	76.06	77.67
	Ave		66.09	62.76	64.19	63.91	65.35	65.04
	Stdev		6.52	5.11	4.79	5.19	5.06	5.56
	CpK > 1.67		2.51	2.99	3.29	3.02	3.18	2.88
	Break Mode	Lifted	0	0	0	0	0	0
		Ball %						
		Break at Neck %	0	0	0	0	0	0
		Break at Span%	95	87	97	90	82	85
		Break at Heel%	5	13	3	10	18	15
	Lifted Stitch%	0	0	0	0	0	0	
Sample Size Readings		40						
Stitch Pull Test	Min > 17 g	NSOL	37.49	36.75	34.19	31.44	30.42	29.5
	Max		51.62	51.7	47.47	44.04	47.68	51.53
	Ave		44.56	43.62	40.33	39.04	38.95	39.9
	Stdev		3.21	4.29	3.33	3.33	3.15	4.75
	CpK > 1.67		2.87	2.07	2.34	2.21	2.33	1.61
	Break Mode	Lifted Ball %	0	0	0	0	0	0
		Break at Neck %	0	0	0	0	0	0
		Break at Span%	3	0	0	3	0	0
		Break at Heel%	97	100	100	97	100	100
		Lifted Stitch%	0	0	0	0	0	0
Sample Size Readings		40						
Remarks		Failed	Passed	Passed	Passed	Passed	Passed	Failed CpK

Table 3. Stitch formation and break mode

	-10%LL	LL	NN	HH	+10%HH
Stitch Formation					
Stitch Pull Break Mode					

Several units were also bonded to check for NSOL and short tail occurrence and none was encountered. Observed good stitch formation on bonded units as shown in Table 3.

Qualification lots were released after definition of final parameter and all qualification lots passed reliability tests requirements. Since then, the device is running in mass production using the defined parameter settings validated on several machines with good wirebond performance and no customer complaint.

5. CONCLUSION AND RECOMMENDATIONS

The study was able to resolve the broken wire at heel issue through the design of experiments (DOE) using thermocompression bonding concept. Optimizing the bond temperature together with the parameters and performing DOE resulted to a robust process satisfying the demand in production. Moreover, package requirements were met in terms of reliability response, resulting to overall customer satisfaction.

Thermocompression ball bonding is an effective way of resolving broken wire at heel issue especially when dealing with thick wires such as the 2 mil Cu wire. Proper parameter setting coupled with optimum bond temperature can help to eliminate broken wire at heel occurrence. Though it is important to increase the bond temperature, it is important as well to know the device requirement especially die specification and temperature tolerance so as not to induce damage or potential malfunction on the device. Works and learnings discussed in [5-11] are helpful to further improve the QFN package assembly manufacturing focused on the wirebonding process.

DISCLAIMER

The company name used for this research is commonly and predominantly selected in our

area of research and country. There is absolutely no conflict of interest between the authors and company because we do not intend to use this company as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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