Stitch Bond Enhancement for X-Wire™ Insulated Bonding Wire

A Technical Collaboration

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INTRODUCTION

Insulated Bonding Wire is an alternative interconnect technology which is gaining acceptance as a viable, cost-effective roadmap solution to enable complex package designs, enhance package performance, and improve the yield of high-density packaging.

The benefits of insulated wire are well known, ranging from wire sweep yield improvement to enabling complex wiring of chip-to-chip packages. To realize these benefits, insulated bonding wire must integrate into the mature wire bond infrastructure and existing package assembly process flow, with minimal capital expenditures. In particular, insulated wire must work with industry standard wirebonding equipment and capillary bonding tools, such as those available from Small Precision Tools (SPT). This is the design point for a new insulated bonding wire technology called, X-Wire™, developed by Microbonds Inc.

During implementation of an insulated wire bonding process, a correct understanding of capillary selection and optimization of bonding parameters are important to achieve best results. This paper describes a technical collaboration between SPT and Microbonds Inc, which evaluated and developed robust process windows for insulated bonding wire.

In this study, a new bonding tool solution is proposed by SPT to improve the stitch bondability for insulated wire by creating a new surface morphology on the tip of the capillary. Known as the Stitch Integrator (SI) capillary, SPT's new SI capillary was developed with the objective to improve stitch bondability of the stitch bonds through better coupling effect between the capillary and the insulated wire during bonding. Experiments of the wire bonding were performed to confirm the effect of the SI capillary on the stitch bondability as compared to conventional capillary.

EXPERIMENTAL METHODS

The 25μm X-Wire™ bonding investigation was carried out on ASM Eagle 60AP wire bond machine using 60μm bond-pad-pitch (BPP)BGA devices. Ball shear and stitch pull tests were performed after wire bonding. The bonding response criterion was minimum 4gf stitch pull. All responses and measurements were taken with a sample size of 25 readings.

The study was performed in two segments; first, bonding comparison between X-Wire™ and bare gold wire with 4N purity using a conventional capillary and second, stitch bondability comparison for X-Wire™ using both conventional and SI capillary.

Bonding experiments were carried out using capillary with the following dimensions.

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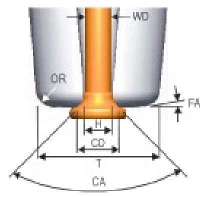
<tr><td rowspan="5">

Cross-Section of capillary tip profile</td><td>Hole Ø</td><td>30μm</td></tr>
<tr><td>Chamfer Ø</td><td>37μm</td></tr>
<tr><td>Tip Ø</td><td>80μm</td></tr>
<tr><td>Face Angle</td><td>11 deg</td></tr>
<tr><td>Outer Radius</td><td>12μm</td></tr>
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RESULTS AND DISCUSSION

A comparison study was carried out to investigate the performance of both the SI capillary and the conventional capillary. Results were discussed based on the bonding response performance for each of the capillary.

<u>Bonding Response Comparison between Bare Au wire and X-Wire™</u>

Bond parameters for the first and second bond are optimized using 25μm bare Au wire with a conventional capillary. Table 1 shows the single point bond parameter as defined for bare Au wire.

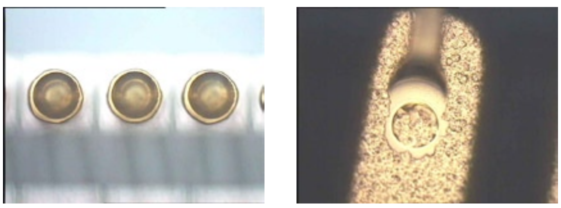
The same set of parameters is then used to bond X-Wire™. The objective is to bond the X-Wire™ under the normal environment and to then be able to make a comparison between the bonding response with the bare Au wire, and the desired bond result with X-Wire™.

Bonding Parameters	Setting	
	First Bond	Second Bond
Bond Time, msec	15	10
Bond Power, Dac	55	65
Bond Force, gf	15	95
EFO Current, mA	4800	
EFO Time, msec	340	

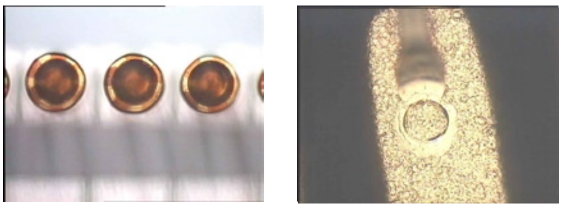
Table 1: Bond Parameter defined for bare Au wire

Wire Type	Bare Wire	X-Wire™
Device	BGA	
Capillary Type	Conventional	
Wire Diameter,µm	25	
FAB Size, µm		
Average	38.00	44.00
Std. Dev.	0.61	1.46
Ball Size, µm		
Average	45.04	48.72
Std. Dev.	0.69	0.84
Ball Height, µm		
Average	11.72	15.98
Std.Dev.	0.72	0.96
Ball Shear, gf		
Average	19.23	19.30
Std. Dev.	0.90	0.76
Stitch Pull, gf		
Average	7.29	3.39
Std. Dev.	0.41	0.45

Fig 1: Bonding response comparison between bare Au wire and X-Wire™

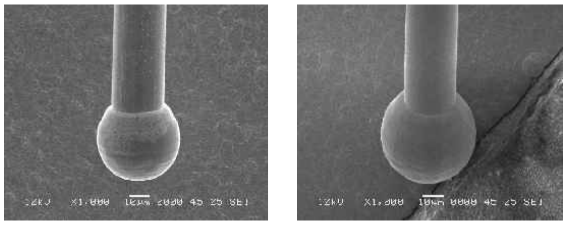


(a)



(b)

Fig 2: Micrograph bonding photos (a) bare Au wire, (b) X-Wire™



(a)

Fig 3: FAB size comparison between bare Au wire and X-Wire™

With a common set of electronic flame off (EFO) parameter settings, the Free-Air-Ball (FAB) size of X-Wire™ is 14% larger than that of bare Au wire. This was mainly contributed by the insulation on the wire. Fig 3 shows the visual difference between the FAB size of bare Au and X-Wire™.

Fig 1 shows the initial bonding response comparison between bare Au wire and X-Wire™. Using the bond parameters optimized for bare Au wire to bond X-Wire™, results in an average ball size and ball height measurement of 49µm and 16µm respectively which is significantly larger than the ball size and ball height of bare Au wire.

This is mainly due to the larger FAB formation with the X-Wire™. In addition, the use of bare Au wire Stitch pull parameters results in Stitch pull readings for X-Wire™ which are 53% lower relative to bare Au wire. This was evident from the poor stitch bond formation for X-Wire™ as shown in Fig 2.

This confirms that bonder parameter optimization for X-Wire™, is a key factor in achieving correct ball and stitch performance for X-Wire™.

Bonding Optimization and Response Comparison between Conventional and SI Capillary

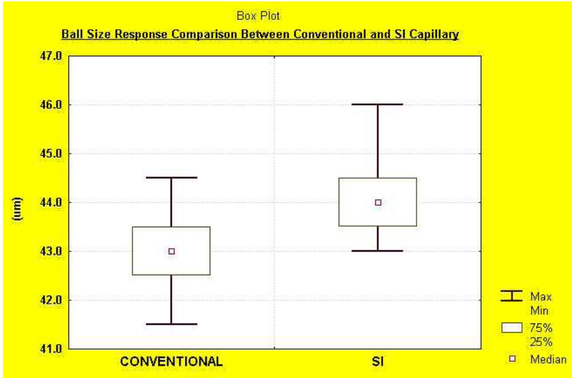
A parameter screening was then conducted to determine the optimum bond parameter windows for the selected 25µm X-Wire™, using both the SI capillary and conventional capillary. For X-Wire™, a different set of bond parameters is required due to the presence of thin layer of insulation on the wire, which of necessity slightly alters the native response of the bare Au bonding wire. In this case, optimum X-Wire™ bond parameters are quite different from optimum bond parameters for bare Au bonding wire.

From the ball shape and size point of view, EFO parameters, particularly the EFO time, must be at least 15% lower than the EFO time used for bare wire. These settings will ensure that the FAB size is optimized to ensure that the final mashed ball size of X-Wire™ is closer to bare Au wire, given a wire diameter of 25µm.

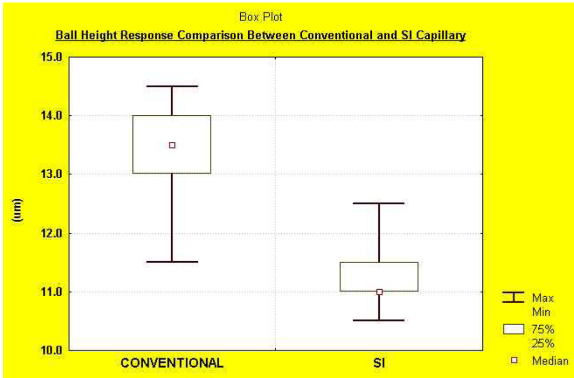
A selected single point parameter was used for bonding comparison with the results as shown in Figure 4 and Figure 5. ASM Wire bonder stitch enhancement functions are very helpful in achieving higher stitch pull readings when this setting is activated. Specialized motions improve the stitch bond above the required specification, to approximately 5.7gf (avg) stitch pull strength using SI capillary. Table 2 shows the single point bond parameter defined for both the conventional and SI capillary.

Table 2: Single point bond parameter for conventional and SI capillary

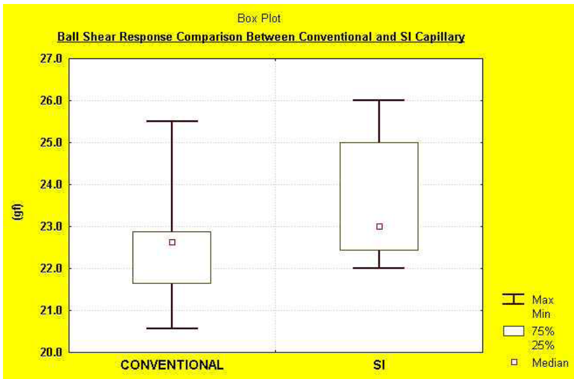
Capillary Design	Conventional Design	SPT's SI Design
Bond Time, msec First Second	 15 8	 15 8
Bond Power, Dac First Second	 53 60	 53 60
Bond Force, g First Second	 13 90	 13 80
Contact Power, Dac First Second	 10 0	 10 12
Contact Force, g First Second	 8 12	 8 20
EFO Current, mA	4800	4800
EFO Time, ms	290	290



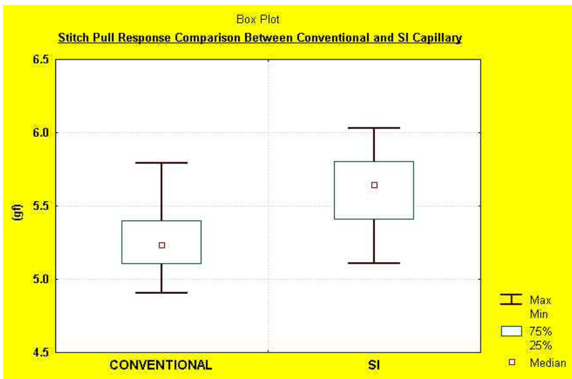
Ball size response



Ball height response

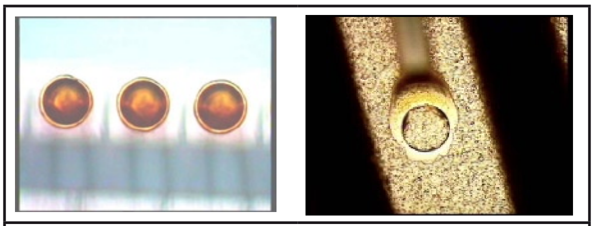


Ball shear response

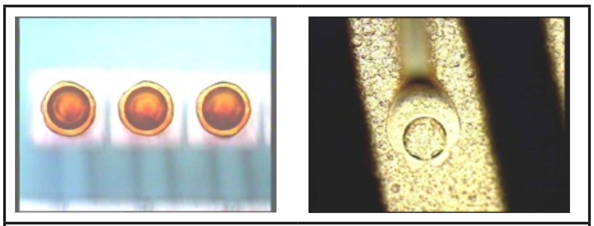


Stitch pull response

Fig 4: Bonding response comparison for conventional and SI design capillary.



(a)



(b)

Fig 5: Micrograph bonding photos (a) conventional capillary, (b) SPT's SI design capillary

Comparing the bonded ball size between the conventional and SI capillary, it can be noticed that the bonded ball size of SI capillary is at least 1µm larger than the bonded ball size of conventional capillary but nevertheless within the acceptable range of the criteria. The ball shear response for SI capillary is found improved when compared to the ball shear response of the conventional capillary.

From the stitch pull response the advantage of SI capillary over a conventional capillary is observed. The data shows that the average stitch pull reading of SI capillary is 7% higher than the average stitch pull reading of conventional capillary.

SUMMARY

The preceding study had helped to identify the following conditions that are important in bonding X-Wire™.

a) SPT's SI capillary design is observed to be more stable to bond X-Wire™ of Microbonds because of its ability to provide higher stitch pull readings.

b) The EFO time must be set at least 15% lower from the EFO time setting of bare Au wire.

c) Wire bond machine second bond enhancement parameter functions are recommended as they clearly provide better sticking capability during bonding, thus achieving higher stitch pull readings.

REFERENCES

[1] "Stitch Integrator – Enhanced Stitch Bondability," Small Precision Tools - Application Note, 2007.

For more information, contact either SPT or Microbonds

Contact Information

Small Precision Tools
SPT Asia Pte. Ltd.
970 Toa Payoh North #07-25/26
Singapore 318992
Phone: +65 6253 5577
Fax: +65 6250 2725
www.smallprecisiontools.com

Microbonds

Microbonds Inc.
151 Amber Street, Unit 12A
Markham, Ontario
Canada L3R 3B3
Phone: +1-905-305-0980
Fax: +1-905-305-1078
www.microbonds.com