Chip Scale Package (CSP) Wire Bonding Capability Study

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Abstract:

The emergence of the new advanced package technology chip scale package (CSP) in the semiconductor industry has been increasingly becoming popular. In this study, the focus will be made on the CSP package types using wire bonding interconnect technology, which was performed to determine the degree of limitation and challenges of having a short and low looping profile as dictated by the allowable CSP package thickness. Two major considerations were studied and investigated, namely: the short and low wire looping profile, and capillary design.

Introduction:

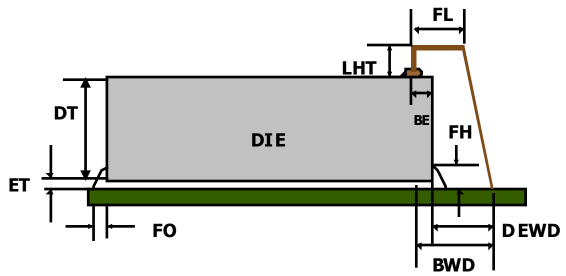
Chip Scale Package (CSP) are commonly designed and used for devices like DRAM, SRAM, flash memories, not so high pin count ASIC, and microprocessors. The main difference of a CSP as compared with other package technology is that the package area is less than 1.20 times the chip area. The unique feature of most CSP is the use of a substrate (interposer, or carrier or substrate carrier, or metal layer) to redistribute the very fine pitch (as small as 75µm) peripheral array pads on the chip to a much larger pitch (1mm, 0.8mm, 0.75mm, and 0.5mm) area array pads on the printed circuit board (PCB). Basically most of the CSP's uses either wire bonding or solder bumped flip-chip technology.[1]

The CSP is seen as a cross between the BGA and flip chip technology due to current board and assembly limitations in handling ultra-fine pitch array packages. The CSP have an advantages – as with the substrate, it is easier to test at high speed and burn-in for known good die (KGD), to handle, to assemble, to rework, to standardize, to protect the die, to deal with die shrink and expand, and it is subject to less infrastructure constraints.[1] The CSP construction and size makes suitable for high lead count I/O (up to 1200).

The present assembly infrastructure (e.g. wire bond equipment, etc...) has matured over the years. Changing from one packaging technology into another means new resources and investment. Given this scenario, the semiconductor assembly houses are pushing the limits of the present equipment's capability to optimize its full utilization for new packaging technology like the CSP wire bonding.

For short and low looping profile, wire bonder looping capability have been investigated and explored to cater the targeted 200µm to 300µm wire span distance, die edge to wedge distance (DEWD)- measured from the edge of the die up to the stitch bond- as it would have a very short proximity clearance.

How close the bond pad distance from the edge of the sawn die also influences the target wire span distance. The further the bond pad is from the edge of the die, the more it adds up to the total wire span looping distance. Having this in mind, it is also of great importance to consider the limits on how the loop can be as close as possible from the edge of the die (DEWD)- targeting <100µm.



DT- Die Thickness BWD- Ball Wedge Distance
LHT- Loop Height FL- Flat Length
ET- Epoxy Thickness FH- Fillet Height
FO- Fillet Overflow
DEWD- Die Edge to Wedge Distance
BE- Distance from Center of the Ball Bond to Die Edge

Figure 1: Schematic Diagram of the CSP Wire Bonding

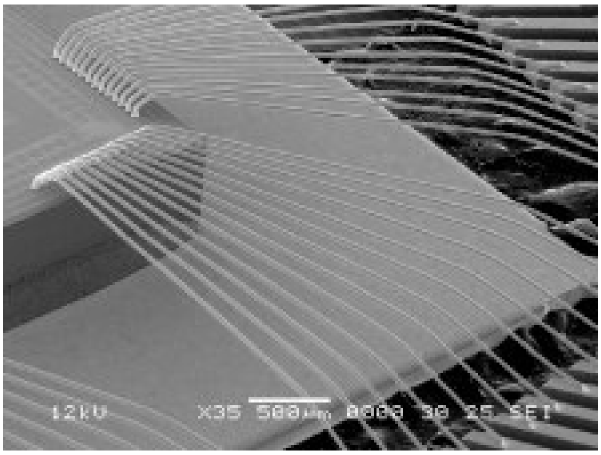


Figure 2:Typical Looping Profile of a Standard Ultra-Fine Pitch 60µm BPP QFP Package

As for the capillary design aspect, consideration has been made to address the tool's deep access capability- considering the following: target loop height (LHT) of less than 100µm; die thickness (DT) of 380µm; epoxy thickness (ET) of 50µm; and die placement accuracy.

Objective:

The objective of this study is to determine the wire bonding capability for CSP considering the low loop and short die edge to wedge distance (DEWD) using the targeted criteria defined below.

	CSP Criteria
Bond Pad Pitch (BPP)	60µm
Bond Pad Opening (BPO)	54µm x 54µm
Loop Height (LHT)	<100µm, ave.
Die Edge to Wedge Distance (DEWD)	<300µm, ave.
Wire Pull Strength (WP)	4.0gmf, min. SD=0.8
Ball Contact Diameter (BCD)	42µm ave. SD=0.8
Ball Height (BHT)	9.5µm, SD=0.8
Ball Shear Readings (BSR)	12.5gmf min, SD=1.6
Bonding Temperature	160°C
Capillary used	SBNE-30ZA-AZM1/16XL 50MTA BNH=500µm

Scope and Limitation:

This study is based on the 60µm bond pad pitch (BPP) platform incorporating the CSP WB targeted requirement. However, the intent is to demonstrate the technology, not a product launching, behind the design feasibility & capability of the CSP capillary bonding tool and of the handling of wire bonder looping.

Actual bonding simulation was done using a PBGA substrate package and die attached the die considering the 1.20X requirement ratio.

Previous study on the material (e.g. Alumina Zirconia) and capillary design selection (e.g. 50MTA) had been performed for ultra-fine pitch application. (Reference: Capillary and Process Optimization for 50µm Bond Pad Pitch- SEMICON Singapore 1999)

Capillary Design:

In this study, there are two basic elements in the capillary design was considered- the ultra-fine pitch 60µm BPP application, and the deep access tool capability for CSP.

As for the ultra-fine pitch 60µm BPP capillary, considerations in the selection for the correct design were made based on the following:

- Ceramic material with Zirconia composite – to withstand the inherent tip breakage due to small tip geometry
- Working 60µm BPP capillary design used for standard QFP/BGA package types- coupled with higher bottleneck height (BNH)

The close proximity of the stitch bond to the edge of the die is the critical factor of consideration for capillary selection for CSP application. This was achieved by increasing the bottleneck height (BNH) to 500µm – to create the necessary clearance of the tool as it travels down to form the stitch bond without hitting the edge of the die. The die thickness (DT), epoxy thickness (ET), and loop height (LHT) were all considered- such that the BNH > ET+DT+LHT.

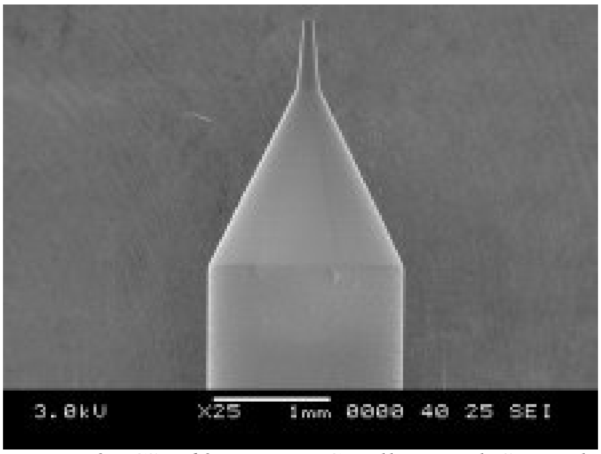


Figure 3: CSP 60µm BPP Capillary with Special BNH of 500µm with Deep Access Capability

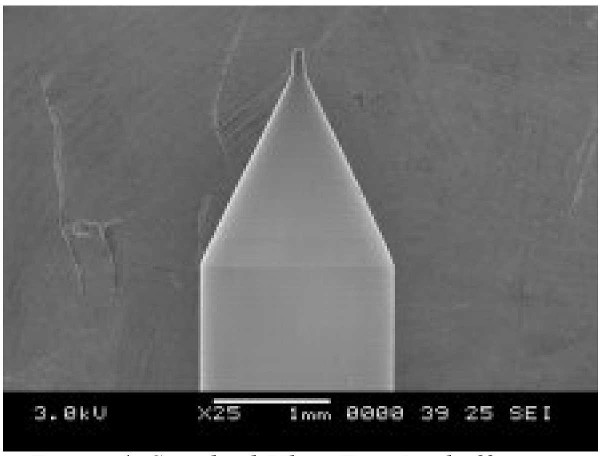


Figure 4: Standard Ultra-Fine Pitch 60µm BPP Capillary with Standard BNH of 200µm

Ultrasonic Study: Comparing Standard Ultra-Fine Pitch and CSP (Deep Access) Capillary Design

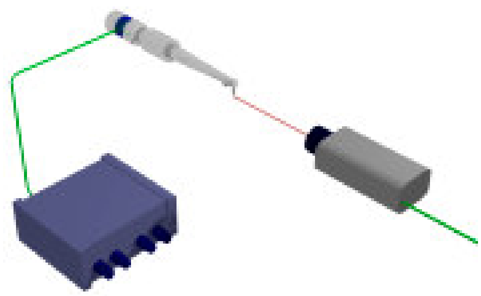
Objective: To determine the amplitude oscillation or displacement (with load condition) at the tip of the same capillary design for 60µm BPP with a different BNH.

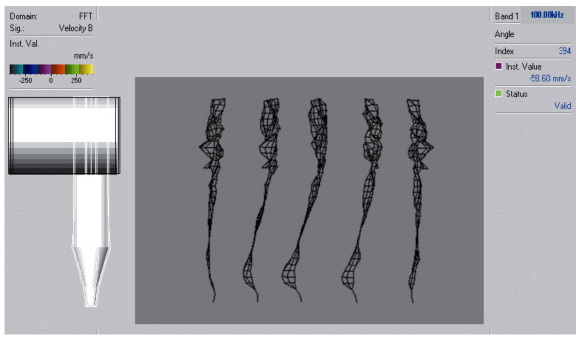
Materials:

- Capillary used:
  - SBNE-30ZA-AZM1/16XL 50MTA with BNH= 200µm- standard capillary design
  - SBNE-30ZA-AZM1/16XL 50MTA with BNH= 500µm- CSP capillary design

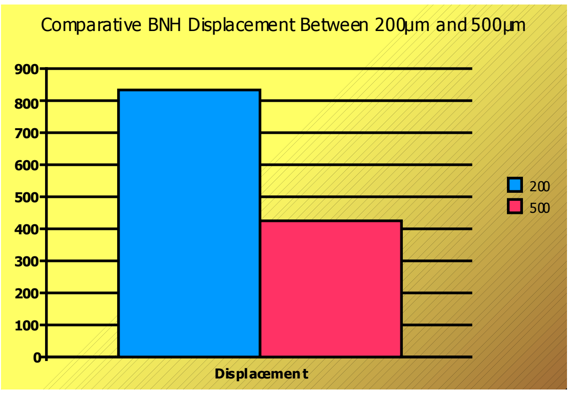
Experimental Set-up:

1. The laser interferometer beam is projected at the tip of capillary-, which is mounted on a 100KHz transducer to measure its amplitude oscillation with load at 40gms.





Data and Results:



Note: Displacement readings are in nm with load using a 100KHz transducer; BF=40 grams

The table shows the difference in the displacement values comparing the BNH of 200µm and 500µm. The former has 830nm and the latter has decreased to 420nm readings- that shows the amplitude oscillation at the tip is reduced by half for the BNH of 500µm.

Ultrasonic Power Settings Used During Actual Bonding of the Standard and CSP 60µm BPP Capillary

Parameter	**BNH 200µm**	**BNH 500µm**	**% Increase**
Ball Bond Power	10%	17.6%	76%
Wedge Bond Power	12%	25.1%	109%

Based on the above table, the BNH of 500µm requires an increase in its power settings in order to attain the targeted response for MBD, BSR, and WP readings.

This has also validated the pre-bonding test done on the same two capillaries for amplitude displacement measurements.

CSP Looping Profile

For the CSP wire bonding, since the major consideration is the die edge wedge distance (DEWD), which is at 200µm to 300µm range, the wire bonder looping software algorithm is able to handle such a kind of short and sharp looping trajectory motion. Potential wire bonding reliability concerns such as the tight looping, wire fracture above the ball, and die to wire shorting must be taken into consideration.

Die placement accuracy is another area of consideration in order to maintain a certain consistency in the short looping formation.

Material & Equipment:

Machine: ESEC 3008 Gold Wire Bonder
with 100KHz transducer
SW release version 53.0
Package: Test Chip with Al 1%Si 0.5%
Cu pad metallization
Wire: 25µm gold wire, Tanaka GMH
Other support equipment:
Scanning Electron Microscope
High Power Scope
Ball Shear/ Wire Pull Tester

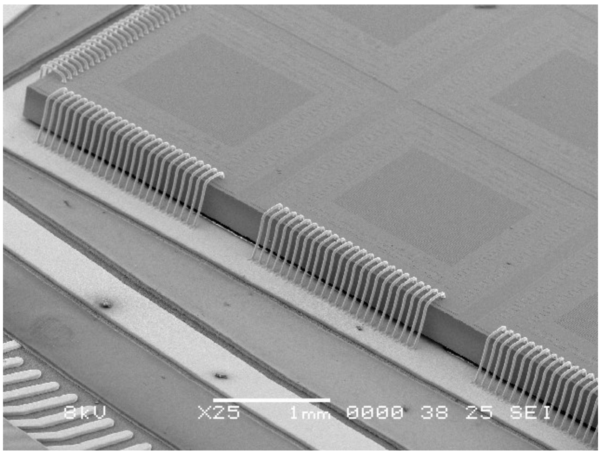
Experimental Approach:

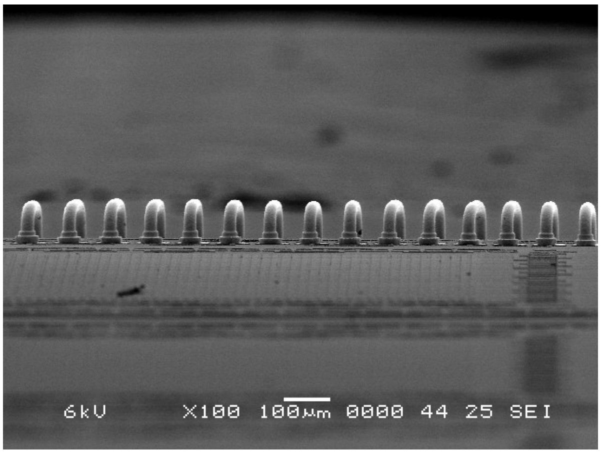
1. Set-up the ESEC 3008 wire bonder using the 60µm BPP pre-determined process window parameters.
2. Install the CSP capillary- SBNE-30ZA-AZM1/16XL 50MTA with BNH= 500µm
3. Adjust the bond parameters accordingly for ball and stitch bonds until the targeted criteria are met.
4. Optimize the looping parameters under loop mode 1 until the desired looping profile is achieved considering the DEWD of less than 300µm.

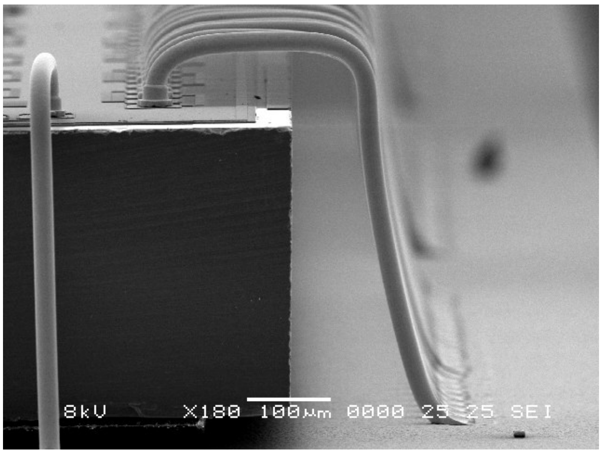
Data and Results:

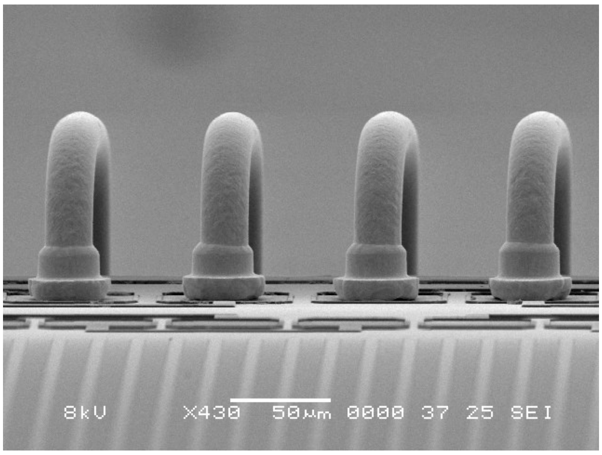
Bonding Response	**CSP**
Mashed Ball Diameter (MBD)	Min.: 42.8µm Max.: 45.1µm Ave.: 44.1µm SD: 0.8µm
Ball Shear Readings (BSR)	Min.: 12.5gms Max.: 15.3gms Ave.: 14.1gms SD: 0.7µm
Ball Height (BHT)	Min.: 10.5µm Max.: 13.0µm Ave.: 12.3µm SD: 1.3µm

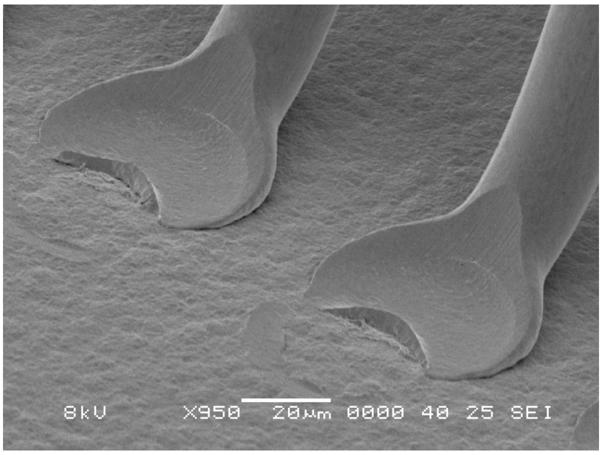
Loop Height (LHT)	Min.: 75.0µm Max.: 90.0µm Ave.: 85.0µm SD: 5.3µm
Die Edge to Wedge Distance (DEWD)	Min.: 210µm Max.: 255µm Ave.: 230µm SD: 13.73µm
Wire Pull Strength (WP)	Min.: 6.1gms Max.: 7.5gms Ave.: 6.86gms SD: 0.47µm











The experiment showed the capability of the CSP wire bonded package based on the following results:

- The wire bonder looping algorithm capability to handle short die edge to wedge distance (DEWD) at an average of 230µm and a low loop height (LHT) average of 90µm without exhibiting any wire fractures above the ball bonds; good looping flat profile; and acceptable bonding response in terms of ball shear readings (BSR), and wire pull strength (WP).

- The special bottlenecked typed capillary design for 60µm BPP using a 25µm wire diameter (WD) having a modified bottleneck height (BNH) of 500µm deep access capability is essential to clear the adjacent loop (without causing interference) as it vertically travels to form the stitch bond without shorting the edge of the die.

Conclusion:

The study showed the feasibility and capability of the CSP wire bonding for the low loop and short die edge to wedge distance (DEWD) using the 60µm BPP test chip based on the following results:

- Low loop capable of less than 90µm loop height
- Less than 250µm die edge to wedge distance (DEWD)
- Acceptable bonding responses for MBD, BSR, BHT, and WP
- A robust high density with Zirconia composite bonding capillary with a modified BNH of 500µm
- Improved looping algorithm with flat length capability
- Short heat affected zone wire types

Acknowledgment:

The authors would like to express its thanks to Mr. Steve Liew and BK Lim of STATS Singapore for providing the resources and needed encouragement; Peter Glutz, and Mary Ong for making all the resources in the PTD laboratory available to make this study a success; Jurgen Steinbichler of ESEC SA and Marcel Wismer and Ralph Binner of ESEC AP for hardware and software upgrades for the ESEC3088 wire bonder; and the PTD group (Winston Bautista, KS Goh, and Jeremy Koh) for the added resource and exchange of ideas.

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