

Thermosonic Gold to Gold Interconnect (GGI) Flip Chip Bonding for 7mm² Die

By

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Abstract

Flip Chip ultrasonic gold to gold interconnect (GGI) has provided a lead free, no clean, process solution for devices with bump counts under 100 for the past five years. The proven reliability and manufacturing cost savings of ultrasonic GGI bonding has now expanded to include large die sized up to 7mm² with bump counts up to one hundred.

The bonding accuracy of the GGI process is +/- 10 μ m. The availability of a voice coil motor with 100N load capability and improved horn design has allowed for the performance improvement in thermosonic GGI flip chip bonder equipment for large die size with high I/O for device packaging.

GGI CSP packaging is used for CMOS sensor, MEMs, RF, memory, and HBLED devices.

Thermosonic GGI bonders use a built in monitoring function for each die bond. The bump collapse height, bond impedance, die X-off, die Y-off, and θ can be "mapped" for each die bond location in real time. The bond map data is stored as a text log file for easy access by downstream test operations.

Gold bonds provide superior bond strength because of the monolithic bond structure of the gold material. Gold bonds also have superior electrical high frequency performance and low resistance when compared to solder or conductive interconnect

processes. Package size reductions are achieved with flip chip thermosonic GGI process when compared to wire bonding. The robust GGI thermosonic process reliably handles gold bump diameter of 60 μ m ~100 μ m in high volume manufacturing.

The GGI process capability has allowed die size reductions up to 70% when compared to wire bonding process. 30% less gold material is used compared to gold wire bonding since the "wire stitch" is eliminated leaving the gold ball for the GGI interconnect.

Flip Chip thermosonic GGI process can bond die with thickness as thin as 100 μ m. This has been an important benefit for mobile device packaging where low profile devices are critical to the market.

Low cost organic substrate materials and embedded passive LTCC substrates are used in flip chip thermosonic GGI device manufacturing. Because the GGI thermosonic uses solid phase micro welding of the die to the substrate, relatively low bonding temperatures <200° C are used in the bond profile.

Thermosonic GGI flip chip process provides fast die attach process time <500msec, a clean process, at low temperature with precision.

Flip Chip Process Comparison

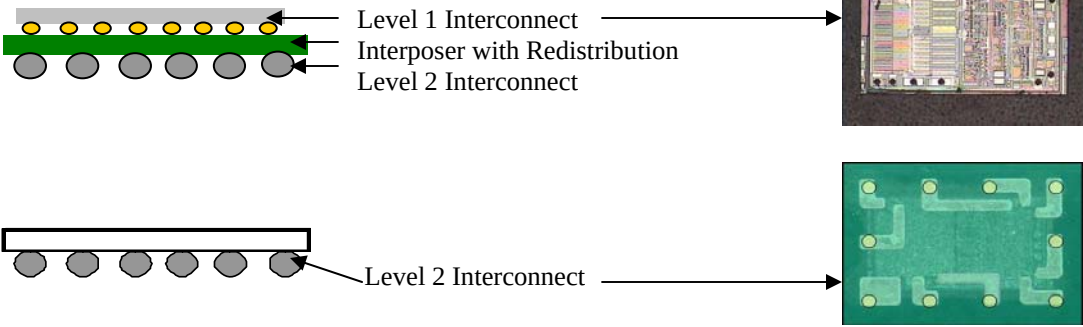
Method	Die Attach Characteristics
Solder	-Alloy metal interconnect
	-SAC solder process temperature 240C~260C
	-Pitch 150mm leading edge
	-Low Bonding Force
	-Self entering component connection
	-Batch Reflowed for high thruput
	-Typically requires underfill to pass reliability
Adhesive	-Contact interconnect
	-Process temperature 100C~150C
	-Pitch 60mm leading edge
	Isotropic Conductive Adhesive (ICA)
	-Adhesive where electrical connection is desired
	-Electrically conductive in all directions
	-Batch cured and underfilled
	Anisotropic Conductive Adhesive (ACA)
	-Adhesive where underfill as well as electrical connection is desired
	-Electrically conductive in one direction
	-Normally individually cured in-situ during bonding process
	Non-Conductive Adhesive (NCA)
	-Adhesive acts as an underfill
	-Adhesive holds electrical connection position
	-Normally individually cured in-situ during bonding process
Microweld	-Monolithic metal interconnect
	-Thermal compression bonding temperature 350C
	-Thermosonic bonding temperature < 200C
	-Moderate to high load applied to collapse gold bump
	-High precision die attach required
	-Lead free, flux free metallurgical bond
	-Individually flip chip die attach during bonding process

Table 1

The flip chip thermosonic GGI process is similar to wire bonding, in that it uses a thermosonic bonding technique. In the case of thermosonic GGI flip chip bonding the bumps are simultaneously bonded to the

substrate. In thermosonic GGI flip chip bonding; traditional gold wire bonds are replaced with gold stud bumps allowing reduction in device packaging profile.

GGI CSP Package Interconnect Low Cost Examples



Gold Stud Bump Methods

Thermosonic GGI process uses a gold stud bump or plated bump. The gold bump can be applied to the interposer or the die. Most bumps are applied to the die rather than the substrate either by wafer

processing (plating) or a gold stud bumping machine. A cost comparison of the different bumping processes is listed in the table below.

Bump Wafer Cost



Table 2 Courtesy Palomar Technologies

Thermosonic GGI Flip Chip Equipment Configuration

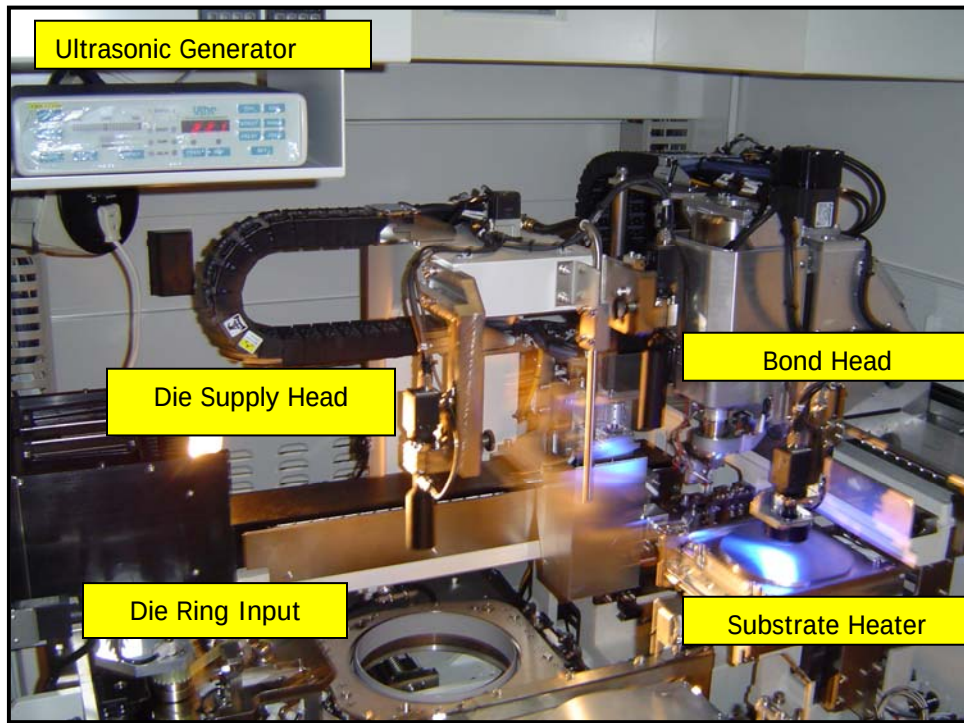


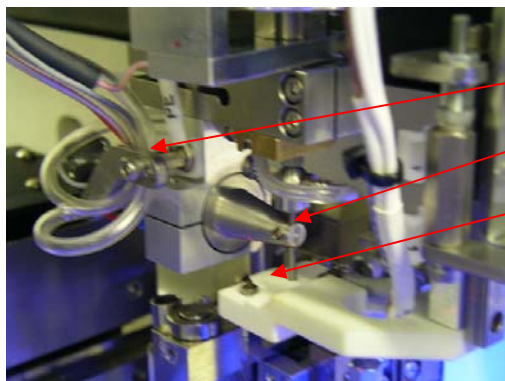
Figure 1 (Thermosonic Flip Chip Bonder Machine Configuration)

Thermosonic Bond Head

The low inertia bond head of the bonder uses a voice coil motor that provides fast linear feedback response of less than 5msec. The VCM load head can be programmed from 1~100N with .01N resolution. The bond head design should have the following features:

- 1)Die attach with lowest possible load, 2)Precise height control (Z axis) with feedback, 3) 100N max VCM, 4)Low inertia bond head with minimum friction forces, 5)20watt capability transducer, 6) 200C maximum bond tool temperature

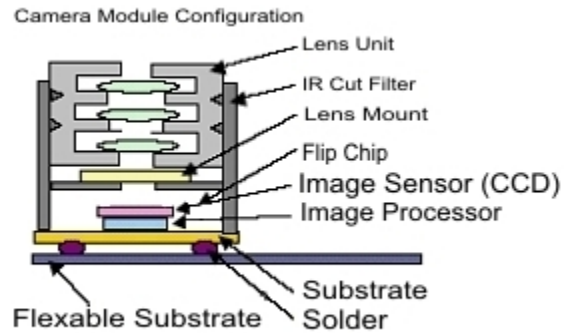
Figure 2



Cell Phone CMOS Image Sensor Level 1 Interconnection

Cell phones require compact CMOS sensor design with high performance. The cell phone camera market specification improvements from 3.2 megapixels to 10 megapixel uses flip chip interconnect. The flipped sensor using back lighting to improve sensor performance. A low profile dense sensor can now be packed into the cell phone.

GGI flip chip provides a clean high performance interconnect for CMOS sensor interconnect with low cost of ownership.



CMOS Sensor Test Materials Bump Measurements and Geometry

Die stud bump geometry measurements shown in figure 3. The die is shown in figure 4 and the substrate is shown in figure 5.

66 Bumps	Bump Height		Bump Diameter		Neck Diameter		Bump Shear Mode	Bump Shear Strength
	Total °m	Base °m	X °m	Y °m	X °m	Y °m	Type	Grams
Max	62	25	73	72	34	33	B.D	32
Min	52	24	71	68	32	32		28
Ave	58	24.4	72	70	32	32.75		31

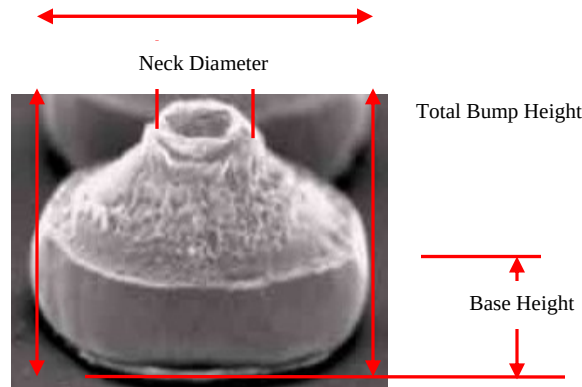
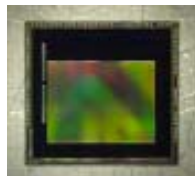


Figure 3 Au Bump Geometry

Figure 4 Die: 6.7mm²

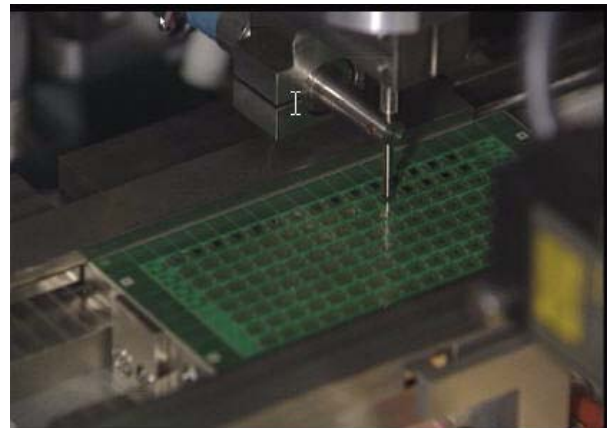


Bottom



Top

Figure 5 BT substrate 50mm x 110mm



Bond Profile

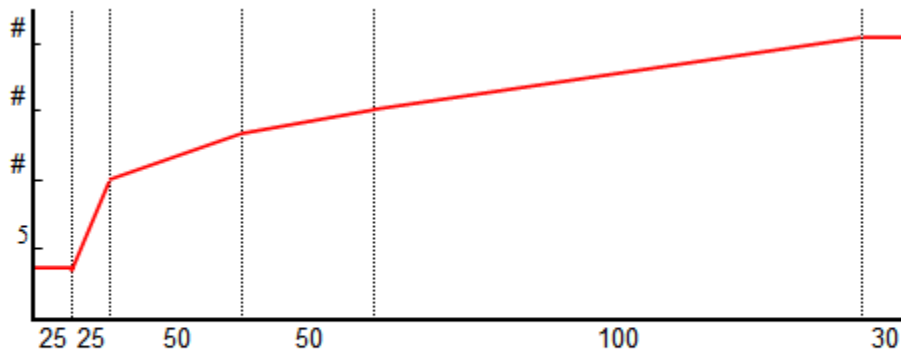
Thermosonic Bond Profile

	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Time (msec)	25	25	50	50	100	30
Load (N)	3	10	13	15	20	20
US Power (mW)			500	1500	2500	30

Substrate Heating 150C

Die Heating 200C

Thermosonic Bond Profile Graph



Result:

Die Shear Strength: 2820 grams

Height : 10 μ m~21 μ m

Process time: 280 msec

Figure 6

The result was a fast 280 msec process time for die attach. The bonding profile heating temperature was

less than 200C. The maximum load applied was 20N (Figure 6).

Mounting Accuracy Data

The mounting accuracy of the bonder can be measured using post bonding inspection camera on the machine. The machine camera measures the X-off, Y-off, and θ die bond measurements. The

criteria is X,Y, = 10 microns @3 sigma, and Theta 0.5 degrees @ 3sigma. Sample measurement accuracy data is shown in figure 7.

Date
M/C#
WO3
Lot#
Qty Pick
DA Yield

Post Bond Inspection								
Bonded Unit#	US(V)	Cycle time(s)	Impedance(ohm)	Bump Collapse(μ m)	X-off(μ m)	Y-off(μ m)	Theta	Judgment
1	2.07	1.13	17.89	12	2	1	0.02	Pass
2	2.06	1.12	17.13	11	-7	11	-0.26	Pass
3	2.17	1.14	17.49	10	-5	-3	-0.01	Pass
4	2.08	1.12	17.93	11	-2	-6	-0.32	Pass
5	2.09	1.13	17.91	10	3	-5	0.02	Pass

Figure 7

Particle Data

Thermosonic bonding the machine operation is done in accordance to class 100 clean level. The CMOS image sensor is sensitive to particle contamination The clean level specification is Class 100 (particles <0.5 microns). Also there can be no contact with image sensor area. The ultrasonic bonder uses a hepa filter and ionizer to maintain clean room operation.

The clean room performance is verified using a particle measuring system at the die supply, carrier table, and wafer table. Typical particle measurements are shown in figure 8.

sample	at supply head	at carrier table	at wafer table
1	100	100	100

Figure 8 Particle Data

Bond Shear Strength and Bump Transfer

Shear strength and bump transfer can be correlated to the bond recipe. Factors such as load, heat, ultrasonic power, and cycle time affect shear strength and bump transfer. The equipment supplier will evaluate several bond profiles in order to meet the customer’s specification for bond strength and bump transfer.

The first step in the bond process is to clean the substrate and die of any particles or residue. Because the ultrasonic process uses solid phase micro welding

it is important that the materials be clean and free of contamination. Batch or inline plasma cleaning process using argon or oxygen is used.

Most equipment allows for at least 10 steps where power, load, time, and temperature can be varied. For the CMOS image sensor die attach the target die shear strength was 2500 grams minimum before underfill. The die shear mode was mode C, D figure 9.

Shear Modes for GGI Flip Chip Die Attach

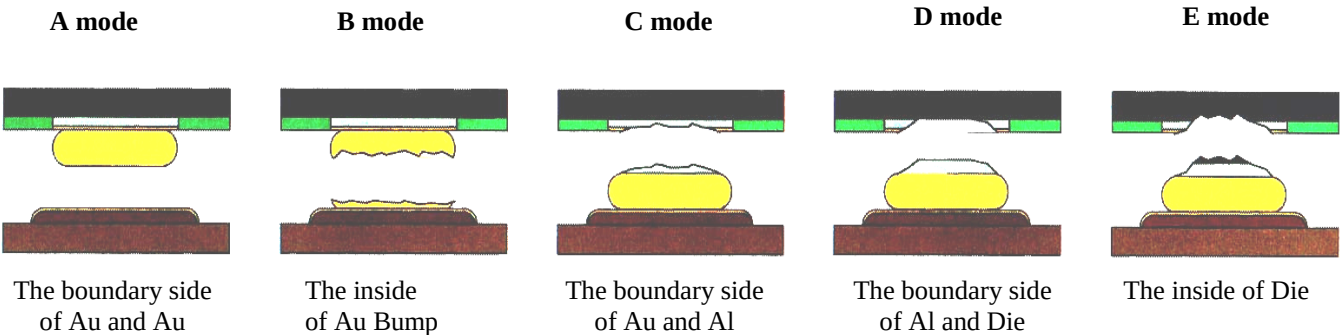


Figure 9 Die Shear Modes

The types of shear mode after ultrasonic bonding are described in figure 14. All bumps are transferred to the substrate. The preferred shear mode for die

bonding is mode “C, D” the boundary side of the Al pad and die.

Conclusion

Ultrasonic has been used primarily for cell phone devices.

Thermosonic flip chip GGI process is expanding

opportunities for cell phone device packaging. GGI process provides excellent quality with good shear forces of over 40 grams per bump for small diameter bumps. GGI process uses solid phase micro welding

which provides a clean precision robust process. GGI flip chip process provides excellent electrical coupling and low electrical resistance for high performance interconnect device packaging. The GGI process uses a monolithic metal bond without the fatigue characteristics associated solder bump die attach.

Thermosonic bonding allows productivity improvement with short process times using heat. Low cost organic substrates materials can be used with GGI process. Since Thermosonic GGI process

uses low temperature bonding low cost materials are an option. Thermosonic flip chip GGI process is competitive with wire bonding productivity and uses up to 30% less gold material. The GGI flip chip has low cost of ownership and has advantage of package size reduction of up to 70% when compared to devices using the wire bonding process.

The improvement in thermosonic GGI process die size handling and clean 100 level operations allowed GGI to be considered for CMOS image sensor interconnect for 10 megapixel cell phones camera.

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