

Improving the Deflection of Wire Bonds in Stacked Chip Scale Package (CSP)

Y.F. Yao, T.Y. Lin and K.H. Chua

Agere Systems Singapore Pte Ltd, 3 Kallang Sector, Kolam Ayer Industrial Park, Singapore 349278

Tel: +65 8402246 (Yao), +65 8402568/9

yyao1@agere.com and tlin@agere.com and khchua@agere.com

Abstract

The deformation of gold wire bonds during transfer molding of stacked chip scale package (CSP) can seriously cause wire crossover and shorting. The major challenges of the stacked CSP development are to reduce the wire sweep (deflection), and make the sufficient space clearance between the wire bonds of first to second die. In this paper, M-shape wire looping program is developed to increase the wire sweep resistance in the stacked CSP. Both linear elastic finite element analysis (FEA) and experiments based on wire bonding and molding process evaluation are conducted. It is found that M-shape looping program is much better than conventional normal wire shape in terms of wire sweep resistance after molding. X-ray and scanning electronic microscopy (SEM) can verify the improvement of wire deflection after chemical decapsulation. It is believed that using M-shape looping program can efficiently overcome the risk of wire shorting and improve the yield of wire bonds in high volume production of stacked CSP.

1. Introduction

There has been a significant demand for stacked die technology in recent years. Stacking of chips in the leaded and substrate package can efficiently minimize package size and cost [1][2]. Stacked leaded and substrate packages can be packed using the conventional IC manufacturing process, e.g., die attach, wire bonding and molding, etc. Some challenges in the stacked die development are thin wafer backgrinding and handling, thermal issue due to the low thermal conductivity of non-conductive die attach paste between die to die and delamination issue due to the package material mismatch, etc. [3][4].

In this stacked CSP development, the most concern is that the wire span from the top die to the substrate is pretty long which is about 3.5mm. The wire deflection is very serious and verified by X-ray after decapping the mold compound if the conventional normal wire looping program is used. The wire sweep issues can be addressed in terms of the deformation along x-y plane and out-of-plane (z direction) [5]-[7]. In conventional IC packages, the wire sweep along x-y plane has attracted the critical attention because this kind of wire sweep can cause wire short if the bond pad pitch is gradually reduced [8]. As for the deflection of the wire along z direction, actually there are no more concerns due to the sufficient clearances between the wire and the die. However, the deflection along z direction could be a crucial worry due to the tight space between two layers of wire bonds if the stacked CSP is built. Especially for a very small top die and relative large bottom die are built in the CSP, the long wires from the top die to the substrate could short the bottom wires [9].

In order to overcome the wire shorting issue, a special M-shape looping program is developed [10]. Compared with the

traditional looping profile with two kink points, the M-shape looping profile has 3 kink points that obviously form the "M" shape as shown in Figure 1. M shape profile pushes the lowest bend point of the wires toward the front span 1 and provides maximum clearance between the upper and lower loops of the wires. From wire bond process point of view, the three-kink point looping profile is more easily controlled compared with the traditional wire loop. The ball shear and mid-span pull strength almost remain the same as the traditional one. It is the excellent engineering exercise to use M shape loop profile to improve the wire deflection in the development of stacked CSP [11].

In this study, 188 pins stacked CSP is identified as the test vehicle. The linear elastic finite element analysis using the commercial FEA code (ANSYS®[12]) is performed to analyze the deformation of the wire bonds during the molding process. The variations of viscosity of the compound and melt front velocity with respect to the wire deflection are discussed extensively for traditional as well as M shape looping profile. Additionally, the experiments in terms of X-ray and scanning electron microscopy (SEM) are conducted to examine and verify the FEA simulation. It is shown that the deflection of wires is improved greatly with the M shape looping profile compared with the traditional one. It is believed that the yield of wire bonds in the high volume production of stacked CSP is increased tremendously as well. The verification on the M shape looping profile with the yield of wire bonds in the volume production is still underway, and could be another study separately.

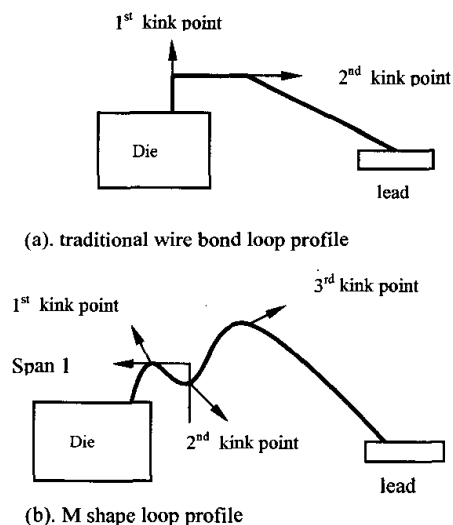


Figure 1. The comparison between the M shape and traditional looping profile for wire bonding process

2. Description of the test vehicle

The 188 pins stacked CSP is identified as the test vehicle. The geometry is defined in Table 1. Figure 2 showed the wire bond diagram of the stacked CSP. Note that the top and bottom wire bonds don't have wire short although they have the overlapping in the plot. The loop profile with different height is shown in Figure 3.

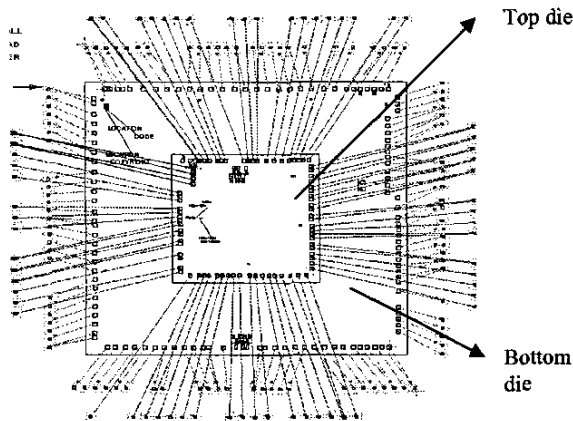


Figure 2. Wire bond diagram for stacked CSP

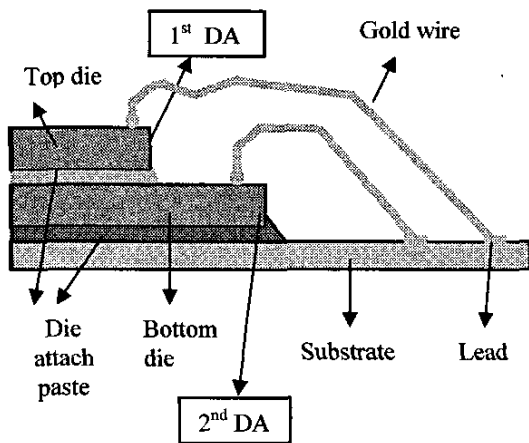


Figure 3. Stacked CSP loop profile for top and bottom die (M-shape was shown at the upper loop profile)

Table 1. The description of 188 stacked CSP

Parameter	Top die (mm)	Bottom die (mm)	Maximum wire span (top die to substrate)	Wire diameter (mil)	Min pad pitch (μm)
Value	2.7mm×2.7mm×7mil	5.85mm×5.84mm×7mil	3.5mm	1.0	75

3. Process flow

Figure 4 showed the stacked CSP wire bonding process. Before wire bonding, plasma cleaning was conducted, and the parameters setting as follows: Time= 10mins, Argon flow=20sccm, Hydrogen flow=0sccm, Filament current=190A, ARC=50A, Plasma deflect=62.5%. The plasma machine is Balzers LFC150. K&S 8028 wire bonder

was used for wire bonding process, the bonding temperature was set as: pre-heat 120°C, bonding heat 135°C, post-heat 100°C. 60μm pitch capillary(H=1.25mil,CD=1.6mil, T=3.5mil, FA=8°) and 1.0mil gold wire was applied. The maximum wire length for top die and bottom die of this stacked CSP are 3.5mm and 1.24mm respectively.

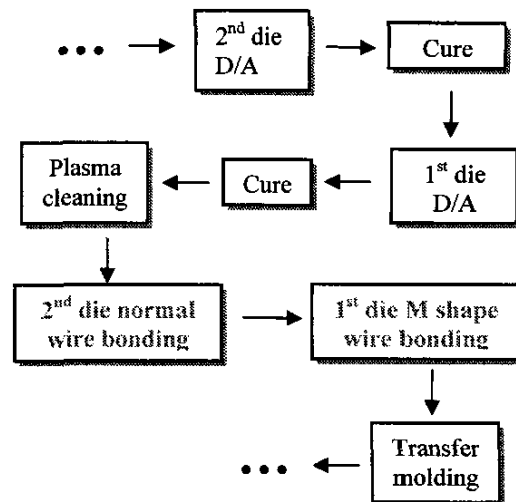


Figure 4. Stacked wire bonding process flow (marked in Figure 3 for 1st and 2nd I process)

4. Wire bonding evaluations

Following the process flow as shown in Figure 4, the conventional wire bonding is performed on the bottom die (2nd bonding) and M-shape wire bonding is carried out on the top die (1st bonding) which can deal with the different wire spans. Actually the plasma clean is implemented to prevent the contamination induced bondability issues due to out gassing from die attaching process before wire bonding. Figure 5 shows the overview of top and bottom wire bonding profiles. Figure 6 shows the wire loop shape for top and bottom wire bonds by using M shape and conventional normal wire bonding respectively. It is noted that the large clearance between top and bottom wire bonds is shown in Figure 6 as well.

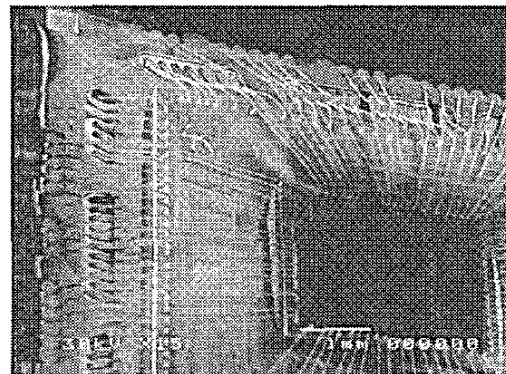


Figure 5. Overview of wire bond loop profile for stacked CSP by SEM

Table 2: Summary of wire bonding results for top and bottom die (sample size: 120)

	Bottom die				Top die			
	Average	STD (σ)	Min	Max	Average	STD (σ)	Min	Max
Ball size (μm)	52.6	0.88	51.0	54.0	52.7	0.86	51.0	54.0
Ball height (μm)	9.0	0.60	8.0	11.0	8.9	0.63	8.0	11.0
Ball shear (g)	22.5	1.23	20.1	25.4	22.3	1.29	20.5	25.0
Ball shear strength (g/mil^2)	6.68				6.60			
Mid-span pull (g)	5.6	0.48	4.8	6.8	5.5	0.50	4.7	6.6
Loop height (die surface to loop top, mil)	4.7	0.25	4.4	5.2	5.8	0.29	5.4	6.3

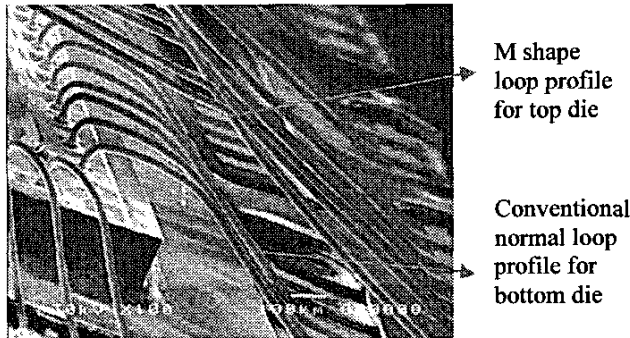


Figure 6. M shape loop profile for top die and conventional normal loop profile for bottom die by SEM

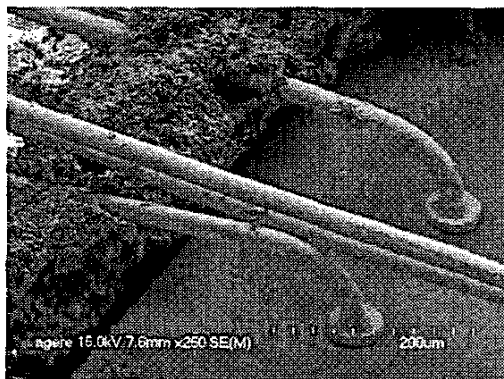
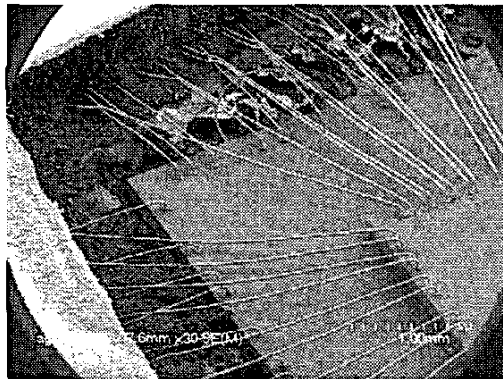


Figure 7. The obvious wire deflection and wire short phenomenon using the conventional normal loop wire bonds for the top die

5. Molding evaluations

The molding process is the final stage to check the efficiency of the M shape wire bonding on overcoming the wire deflection. Figure 7 demonstrates the wire short phenomenon using the conventional normal wire bonding for the top die using the chemical decapsulation technology after molding. It is found that the conventional normal wire bond has the weak bend resistance. Compared with conventional normal loop wire bonding, the M shape wire bond program has an obvious advantage over the conventional normal loop wire bond as shown in Figure 8. The bend resistance of the M shape wire bond is rather high and no obvious deflection of wire bond is observed. As seen in Figure 8, the clearly clearance (2.5–3.5mil) exists between the top and bottom wire bonds. Additionally, there are no any exposed wires found when the M shape loop profile is used in this study.

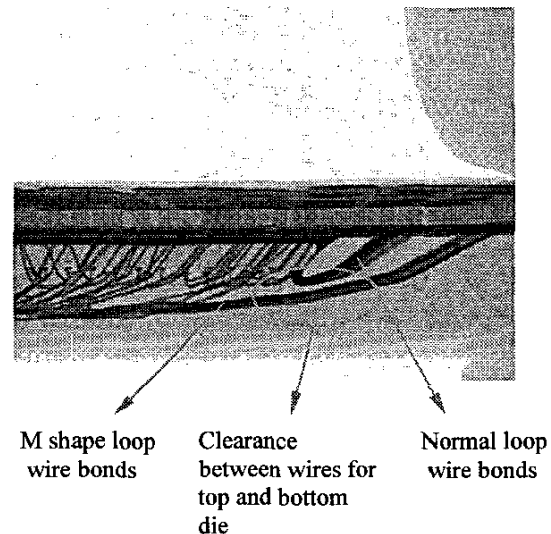


Figure 8. SEM photo on the clearance between the top and bottom wire bonds for stacked CSP using M shape loop profile

6. Finite element model

The objective of the finite element analysis is to address the deflection of M shape wire bond during the molding process. Moreover, the improvement of M shape wire bond on the clearances between the wire bonds for the top and bottom die is illustrated. In order to understand the deflection of the wire bonds during the molding process, the normal forces

(shown in Table 3) acting on the wires are used from [5] that has taken into account the effects of the viscosity and melt front velocity variations. The viscosity is varied from 30 poise to 120 poise based on the specification of the compound supplier. The melt front velocity is changed from 8 seconds to 13 seconds due to the capability of the molding process. The beam elements are used to numerically simulate the wire bond response on the deflection using the commercial software, ANSYS®6.1[12]. The uniform force distribution is acting on the whole wires during the molding process. Table 3 shows the material properties and the deflection results. As shown in Figure 9 and Figure 10, the deflection of M shape wire bond is reduced greatly and also the lowest bending point is pushed toward the die bond location. Hitherto, the clearance between the wires for top and bottom die is improved tremendously. It is also found that the risk of M shape wire bonds is reduced a lot compared with the normal one because the more clearance can prevent the probability of wire short.

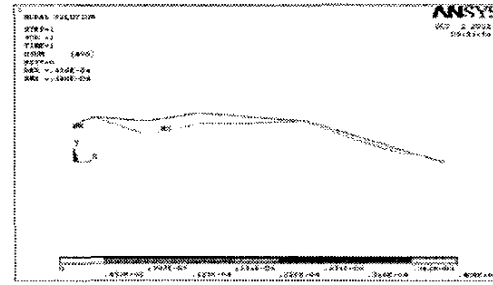


Figure 9. Deflection of the M shape wire bonds during the transfer molding process (case 3 condition)

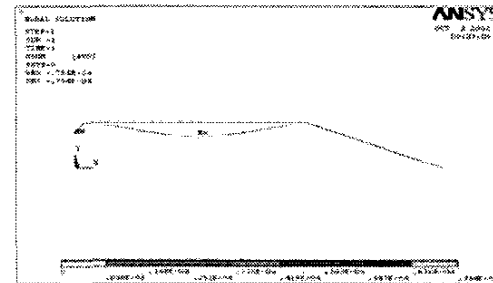


Figure 10. Deflection of the normal shape wire bonds during the transfer molding process (case 3 condition)

Table 3. The simulation results of deflection of both normal and M shape wire bond (Young's modulus: 78Gpa[13], poisson ratio: 0.44[13], viscosity: 30-120 poise, stroke of the compound pellet: 1.8mm, transfer time: 8 sec –13 sec. molding temperature: 175°C, original clearance between top and bottom wires: 3.0mil)

Condition	Parameters	$f_n = \frac{8\pi\eta V_n}{2\ln\epsilon + 1}$ ($\times 10^4$ N/m)	Max wire sweep for 2 loop shapes		Min clearance
Case 1	Viscosity: 30 poise/transfer time: 8 sec	15.6	Normal shape	18.9 μ m (0.74mil)	57.3 μ m (2.26mil)
			M shape	10.1 μ m (0.40mil)	66.1 μ m (2.60mil)
Case 2	Viscosity: 30 poise/transfer time: 13 sec	9.62	Normal shape	11.6 μ m (0.46mil)	64.6 μ m (2.54mil)
			M shape	6.3 μ m (0.25mil)	69.9 μ m (2.75mil)
Case 3	Viscosity: 120 poise/transfer time: 8 sec	62.5	Normal shape	75.5 μ m (2.97mil)	0.7 μ m (0.03mil)
			M shape	40.6 μ m (1.60mil)	35.6 μ m (1.40mil)
Case 4	Viscosity: 120 poise/transfer time: 13 sec	38.5	Normal shape	46.4 μ m (1.83mil)	29.8 μ m (1.17mil)
			M shape	25.0 μ m (0.98mil)	51.2 μ m (2.02mil)

f_n : the normal component of the force acting on unit length of the wire segment, V_n : Velocity component that flows across the wire segment, ϵ : the ratio of wire length to wire diameter, η : mold compound viscosity.

7. Conclusions

M shape wire bond is widely evaluated during wire bond and molding process. SEM, X-ray and finite element analysis are used to study the wire loop profile and deflection of wire bonds. It is found that M shape wire bonds can efficiently overcome the deflection of wire bonds and reduce the risk of the wire short for the long wire bonds in the development of stacked CSP. The finite element analysis can screen the deformation of the wire bonds along the z direction and provide the optimization tool to design and optimize the M shape of wires. Additionally, it is noted that the M shape wire bonds can be easily controlled, and no any exposed wires found after molding process. Therefore, the feasible M shape wire bonds can be launched to the mass production in order to obtain the high yield of wire bond and molding process.

Acknowledgments

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