

Reliability of anisotropic conductive joints for bumpless flip-chip on flex packages under thermal stresses

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Abstract

The reliability of ACF (Anisotropic conductive film) interconnection is a serious concern especially under thermal loading condition. This paper focuses on the online contact resistance behavior of the ACF joint for bumpless flip-chip on flex packages during different thermal cycling conditions. In this work, flip chips of $11 \times 3 \text{ mm}^2$ having bare aluminum pad were used. Real time contact resistance (i.e. live measurement contact resistance variation with temperature) was measured by four points probe method when the packages were inside thermal shock chamber.

Tests for three different thermal cycling profiles (125°C to -55°C , 140°C to -40°C and 150°C to -65°C) were carried out. The samples bonded at temperature 180°C and pressure of 2.42 Mpa was used. The initial contact resistance of the bumpless samples was 0.4Ω . Contact resistance increased with the number of thermal cycles, however the effect was severe when the temperature variation was above the glass transition temperature (T_g) of the ACF matrix (131°C). Differences in co-efficient of thermal expansion (CTE) between the chip and the substrate generated thermal stresses during temperature fluctuation, which caused the pad of the substrate to slide over the Al pad of the chip. Thus variation of the contact resistance was also observed along the interconnection position in the package, i.e. corner joint showed higher value of increase in contact resistance than the middle position. Even though flex substrate was used in this study; the sliding effect was severe at the corner Al pads of the chip, where cumulative forces generated due to the thermal stress. Results show that for thermal cycling profile 140°C to -40°C , online contact resistance increased to 1.2Ω in corner joint, whereas for the middle joints the contact resistance just increased to 0.5Ω . Glass transition temperature (T_g) of the ACF material plays an important role on the high temperature contact resistance. For every thermal cycling profile, there is an incubation period that would have significant impact in the application of ACF. After the incubation period the contact resistance increases rapidly and the joints are no longer reliable.

Key words

Anisotropic conductive film (ACF), Online Contact resistance, reliability, Coefficient of thermal expansion, Thermal warpage.

1. INTRODUCTION

Flip chip bonding using Anisotropic conductive film (ACF) has become wide spread, driven by the demand for smaller size, lighter weight and lower cost portable electronics products such as laptop computer and mobile phone products. Again, as it is lead free, it serves as an environmental friendly material for electronics goods and it requires only simple processing at low temperatures [1], [2]. Due to the greater demands in the electronic

industry for the fine pitch I/O, higher circuit performance and miniaturization, ACF is now used by a large number of the electronic manufactures for the chip on glass (COG) or chip on flex (COF) in their products.

ACF consists of an epoxy adhesive and the conductive particles (3-10% volume fraction) dispersed in the adhesive matrix. The bonding process for the ACF interconnection involves simultaneous application of heat and pressure. During bonding process, the adhesive resin is squeezed out

and the conductive particles are trapped between the pad of the chip and the pad of the substrate. Due to the applied pressure, conductive particles are deformed between the pads. A typical bonding is shown in Fig. 1. Consequently, electrical conduction in ACF interconnection is restricted to the z -direction while electrical insulation in x - y plane is maintained. At high temperature ACF matrix get cured and the interconnection becomes stable. From the above bonding procedure, it is clear that ACF interconnection depends only on the mechanical contact of the conductive particles. On the other hand solder joints depend on the firm metallurgical bonding between the pads using low melting alloys. Hence, although ACF bonding has many advantages over solder joining technology, it suffers considerable limitations, mainly on the issue of electrical reliability at the interconnection [3]. The unstable contact resistance of ACF joint is a main concern before its wide spread application [4], [5]. When an electronic assembly is subjected to temperature changes, thermal stresses develop in the assembly [2]. The stresses generated due to the coefficient of thermal expansion (CTE) mismatch of the materials may lead to warpage [6] in the assembly, which is known as thermally induced warpage. This problem has a major effect on the reliability of the electronic assembly. The thermally induced warpage directly affects the interconnection between the chip and the substrate causing a poor integrity in the assembly and may limit the lifetime of joints [7]. Again, it is known that ACF joints bonded to the non-noble metals shows high increase in contact resistance due to the formation of metal oxides. To retain the low and stable contact resistance, a noble metallurgy, such as gold-to-gold interconnection is required. However, gold plating introduces extra cost. Instead of using gold, bare aluminum pads may be a good alternative as it satisfies the requirement of electronic packaging such as high density, lightweight and cost reduction.

Although the ACF technology for bumpless flip-chip seems to be a breakthrough in fine pitch interconnections, systematic fundamental research work in this topic has not been carried until now. As the thermal behavior of ACF packages is not well known, the need for understanding the thermal performance is crucial for accurate prediction of general mechanical and electrical performance of packages under certain constraints [8]. Contact resistance response during thermal warpage is a critical issue to be studied because when the chip is under operation, it generates lots of heat, which might affect the reliability of ACF interconnection. Unbalanced stress caused due to thermal mismatch in the assembly tries to move the chip pad and substrate pad against each other. As a result, the contact area of conductive particles with the pads decreases and the contact resistance increases [9], [10]. However, there is no

work reported elsewhere on the real-time contact resistance of ACF joint for bumpless flip-chip on flex packages that is operated at higher temperature or below the room temperature.

This study has focused on contact resistance variances of the ACF joint for bumpless flip-chip on flex packages during temperature cycling test. Measuring the online contact resistance for different environmental conditions allows us to understand the effect of CTE mismatch issue between the flex and chip on the reliability of system. Moreover, two different pad positions (middle and corner) of the chip are compared with a view to understand the effect of chip design on ACF joint reliability.

2. EXPERIMENTAL PROCEDURE

2.1 Chip, substrate and ACF

The dimensions of the test chip are 11mm x 3mm x 1mm and a total of 368 Al pads on the periphery. There are 60 daisy chained Al pad groups (each set contains 5 Al pads in which first 3 are interconnected as shown in reference [11]) that run parallel to the length of the chip for electrical connection and another 68 bare Al pads along the width to contribute to the mechanical support. There are no bumps on the test chip. Bare Al pad is used for direct interconnection with the ACF. The thickness of Al pad is 2 μm . The pitch of the Al pad varies from 10-25 μm .

The Flex substrates are 50 μm thick polyimide film with Au/Ni/Cu electrode and daisy chained circuit pattern was developed to match with the pad pattern of the die. The dimension of the substrate is 50x50 mm^2 . The metal pad on the flexible film consists of approximately 12 μm thick copper, electro plated 4.0 μm thick nickel and 0.5 μm gold plating on top.

The ACF, used in this study, is around 35 μm thickness before bonding. The ACF matrix is made of epoxy resin. The conductive particles dispersed in the ACF matrix are nickel and gold-coated polymer of diameter 3.5 μm . The concentration of the conductive particles is about $3.5 \times 10^6/\text{mm}^3$. ACF contains an insulation layer on the top of the film. The ACF becomes cured and set when it is subjected to thermo-mechanical compression during bonding. From the earlier experiments we have carried out [12], we found the glass transition temperature (T_g) of the ACF used in the study is about 131°C.

2.2 Bonding process

The substrates were carefully washed using organic solvent before bonding in order to remove any organic contaminant that might have adverse effect on the ACF interconnection. Prior to experiments, the ACF was stored in a freezer at -50°C . The ACF was cut to correct size in order to cover the area for bonding. Pre-bonding of the sample was carried out by using Karl Suss manual flip chip bonder (model no. K15040-3) using a low pressure and low temperature for a short time. The method of pre-bonding and final bonding

was depicted in reference [12]. After the pre-bonding, the cover film of ACF was peeled off from the adhesive film. The final bonding was done using Toray semi-automatic flip chip bonder (FC 2000). The substrate pads and the position of the chip pads were aligned simultaneously in order to get a high precision bonding. Finally, the chip was bonded onto the substrate by applying heat and pressure as shown in Fig.1. The detail specifications of the bonding parameters are summarized in the Table I. Optical image of the assembly after bonding is shown in Fig. 2.

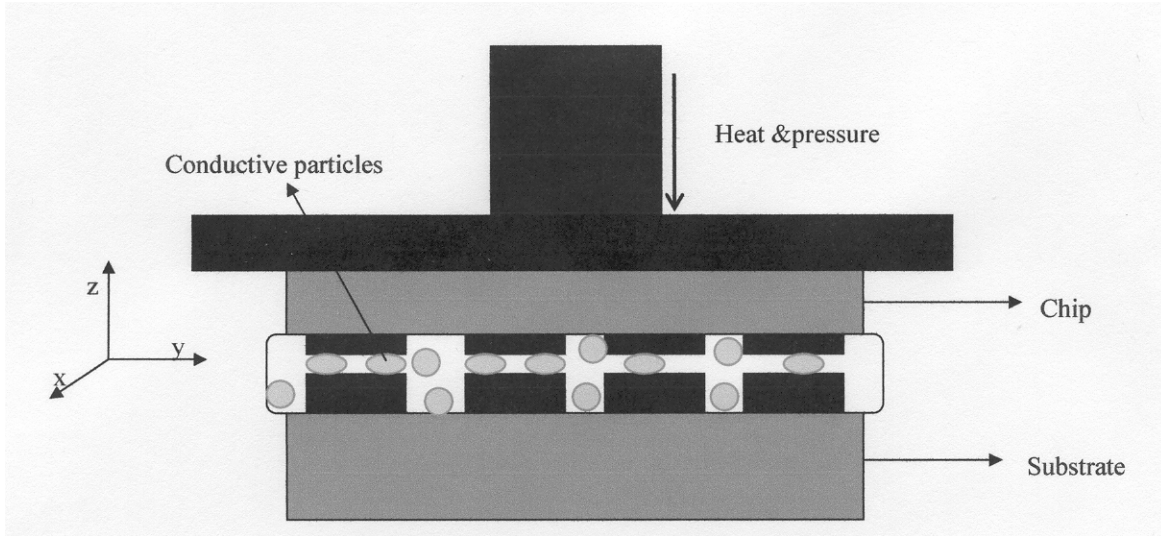


Fig. 1. Schematic diagram showing the process of bonding using ACF.

Table 1. Detailed specification for prebonding and final bonding

Bonding parameter	Pre- bonding	Final bonding
Temperature	100 ($^{\circ}\text{C}$)	180($^{\circ}\text{C}$)
Pressure	0.8Mpa	2.42Mpa
Time	7 sec	15 sec

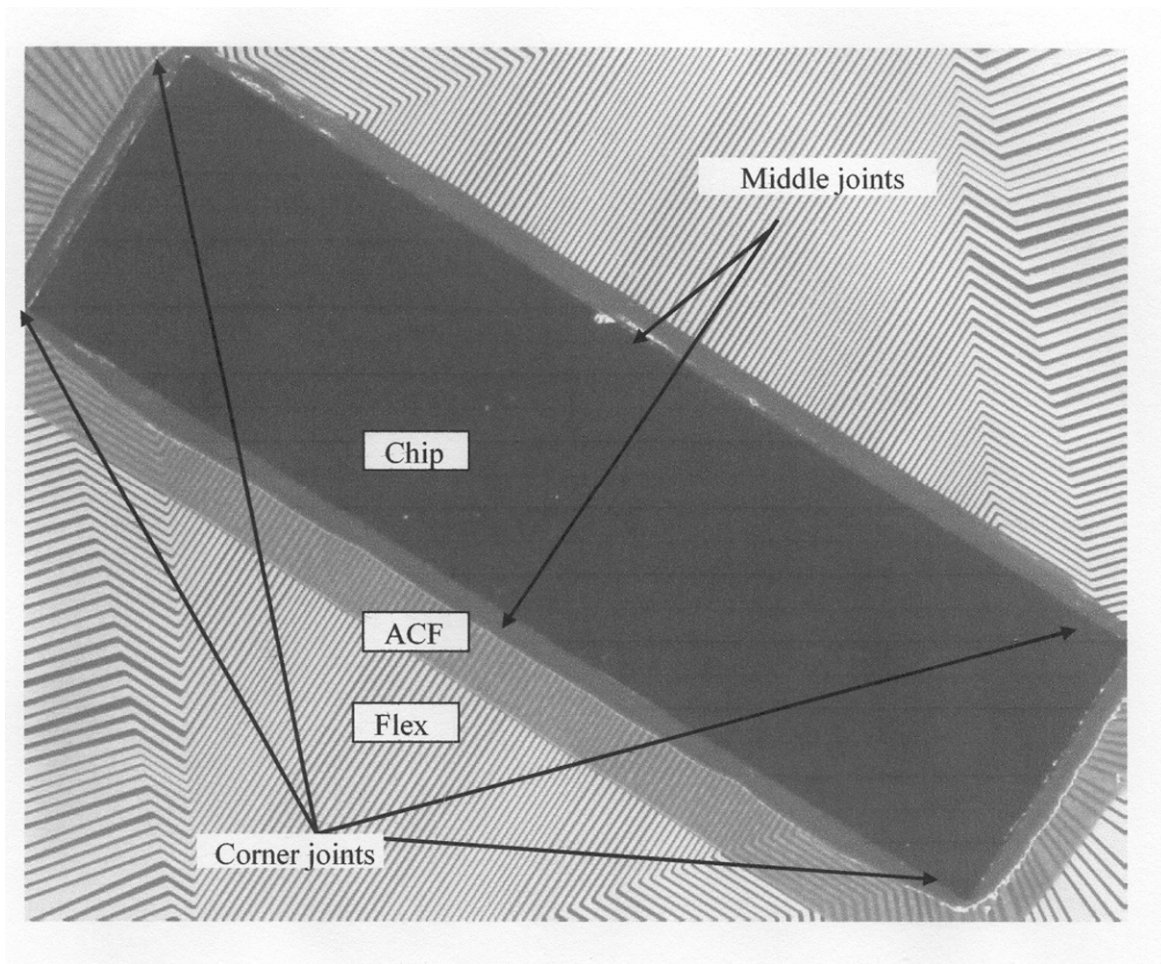


Fig. 2. Optical image of the assembly after the bonding.

Table 2. Details of thermal cycling profiles used in the experiment

No	High temp (°C)	Low temp (°C)	Dwelling time (Min)	Time for Interchange (Min)
1	140	- 40	30	5
2	125	-55	15	2
3	150	-65	15	3

Table 3. Material Properties used for calculation of shear strain [19]

Material	Thickness h (mm)	Young Modulus E (MPa)	CTE $\alpha(10^{-6} \text{ ppm/K})$	Poisson's Ratio (ν)
Si	1	131700	2.7	0.3
Polyimide	0.07	4000	20	0.3
ACF	0.018	899 ($<T_g$) 542 ($>T_g$)	70 at 403K 150 at 463K	0.3

2.3 Contact resistance measurement

The contact resistance of the FCOF (Flip Chip on Flex) assemblies was measured using four-point probe method as described in reference [11]. The online contact resistance was measured through heat resistant wires when the packages were inside the thermal shock chamber. The four tips of the wires were soldered very accurately to the corresponding four point output terminals of the flex substrate. Thus the contact resistance was monitored when the samples were both in hot chamber and cold chamber.

2.4 Thermal cycling

A Feutron GmbH TSRK200 type Thermal cycle test chamber was used to get online contact resistance during thermal warpage. The online contact resistance was effectively measured during thermal cycling. Three different thermal cycling profiles used in the experiment are summarized in the Table 2.

2.5 Failure analysis

The failure analysis of the ACF joints after the thermal cycling was carried out using a PHILIPS XL40 scanning electron microscope (SEM). For interfacial microstructure examination, the samples were mounted in epoxy and then sectioned using a slow speed diamond saw. The cross-sectioned samples were ground and polished carefully for (SEM) study. Back Scattered Electron mode (BSE) of SEM was used to understand the extent of damage occurred in the interconnection. As-bonded samples were also investigated to compare the change occurred during the thermal cycling.

2.6 Theoretical analysis of shear strain in the assembly

High shear stress and strain are developed on the ACF

joints during thermal loading, which may cause conductive particle dislocation or damaged particle leading to a failed joint. It is believed that the shear strain at a particular joint from center of the chip is directly proportional to the temperature. An analytical solution of thermally induced stresses and strains in the bonded joint of a trilayer structure was derived by E. Suhir [13]. The results obtained using the equation can give us an idea about the thermal strain behavior. The shear strain on layer (acf) can be calculated as below.

$$\gamma_{acf}(x) = k \frac{2\Delta\alpha\Delta T \sinh kx}{3G_{acf}\lambda \cosh kL} \longrightarrow (1)$$

The parameters are defined as below:

$(i) = 1, 2, acf$	Layer for which the shear strain is to be calculated Layer 1 = Chip Layer 2 = flexible substrate
$\Delta\alpha$	CTE difference between chip and substrate
ΔT	Temperature gradient
x	Distance from the centre of die
$2L$	Die length

$G_i = \frac{E_i}{2(1+\nu_i)}$	Shear modulus of layer (i)
E_i	Elastic modulus of layer (i)
ν_i	Poisson's ratio of layer (i)
$D_i = \frac{E_i h_i^3}{12(1-\nu_i^2)}$	Flexural rigidity of layer (i)
h_i	Thickness of layer (i)
$D = D_1 + D_2 + D_{acf}$	Total flexural rigidity
$h = h_1 + h_2 + h_{acf}$	Total assembly thickness
$\lambda = \frac{(1-\nu_1)}{E_1 h_1} + \frac{(1-\nu_2)}{E_2 h_2} + \frac{h^2}{4D}$	Axial compliance

$\kappa = \frac{h_1}{3G_1} + \frac{2h_{acf}}{3G_{acf}} + \frac{h^2}{3G_2}$	Interfacial compliance
$k = \sqrt{\frac{\lambda}{\kappa}}$	Interfacial shear stress

Equation (1) can be used to estimate the induced shear strain on particular joint. Material properties used for calculation of induced shear strain are listed in Table 3.

3. RESULTS AND DISCUSSION

The mean contact resistances of the ACF joint before thermal cycling at the four corners as well as at the mid-points of a chip as shown in Fig. 2 were measured and it was found to be around 0.4 Ω . The online contact resistance measured for different thermal cycling profiles (125°C to -55°C, 140°C to -40°C and 150°C to -65°C), gave an idea about the response of ACF joint to thermal loading. The measurement done at the middle and corner of the chip distinguished the magnitude of damage in the different locations of the chips during thermal warpage. There were many open joints identified after the thermal cycling but the study in this paper only concentrates on the online contact resistance variations and its effect on reliability of the assembly.

The online contact resistance for samples subjected to thermal cycling conditions 150°C to -65°C is shown in Fig. 3. The initial contact resistance was 0.4 Ω and it increased to 8.2 Ω in hot condition and 5.9 Ω in cold condition after 100 cycles. The increase in online contact resistance was very high for both hot and cold temperature. The difference between the hot chamber characteristic curve and cold chamber characteristic curve was high and noticeable.

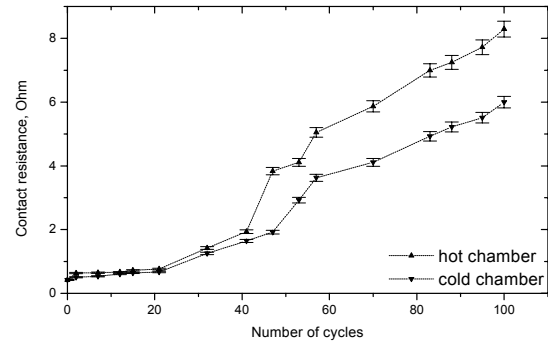


Fig. 3. Variation of online contact resistance with number of cycles at corner pad of chip during thermal cycling profile (150°C to -65°C).

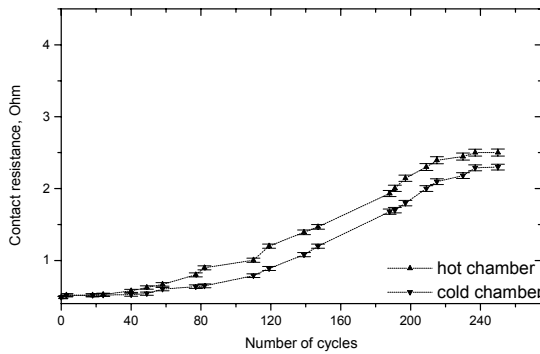


Fig. 4. Variation of online contact resistance with number of cycles at corner pad of chip during thermal cycling profile (140°C to -40°C).

Fig. 4 shows the online contact resistance curve for the thermal profile of 140°C to -40°C. The contact resistance variance during the initial cycles progressed slowly and then increased gradually. However, the rate of online contact resistance increase was high at particular number of cycles leaving the rate of resistance increase unpredictable. The initial contact resistance was around 0.4 Ω and the online contact resistance after 180 cycles was around 2.6 Ω . The difference between the hot and cold curves was 0.2 Ω during 180th cycle, which is negligible, compared to the previous thermal cycling condition.

Fig. 5 shows the contact resistance behavior for the thermal cycling profile of 125°C to -55°C. As the temperature in the hot chamber is lower than the T_g the curve characteristics was totally different than that of the other two cycles. As shown in Fig. 5, the initial contact resistance was around 0.4 Ω and it increased to 1 Ω after 500 cycles. Unlike the other thermal profiles the difference between cold chamber characteristics curve and hot chamber characteristics curve was very low. The difference between hot and cold characteristic curves was 0.1 Ω during 500th cycle.

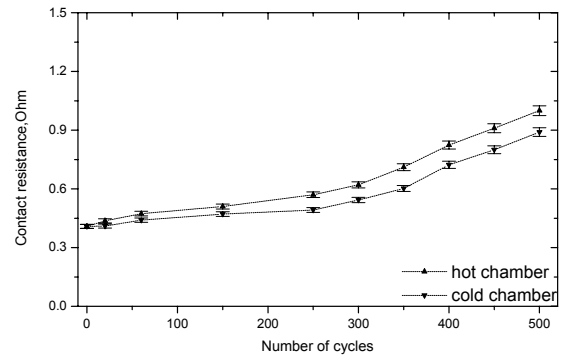


Fig. 5. Variation of online contact resistance with number of cycles at corner pad of chip during thermal cycling profile (125°C to -55°C).

The online contact resistance curve at the middle joint of the FCOF assembly during thermal profile of 140°C to -40°C is shown in the Fig. 6. During very initial stages, both in hot and cold chamber, the contact resistances increased at higher rate and the rate of increase gradually went down as the number of cycles increases. After 80 cycles, the increase was negligible. The increase of resistance at the hot chamber was much higher than that of the cold chamber. The similarity between both the hot and cold was that the increase of resistance sustained only up to around 90 cycles. After 90 cycles, the contact resistance never increased till the end of the thermal cycling test. The online contact resistance at the corner position of the same type of chip during thermal profile of 140°C to -40°C is shown in Fig. 3 and described in the previous section.

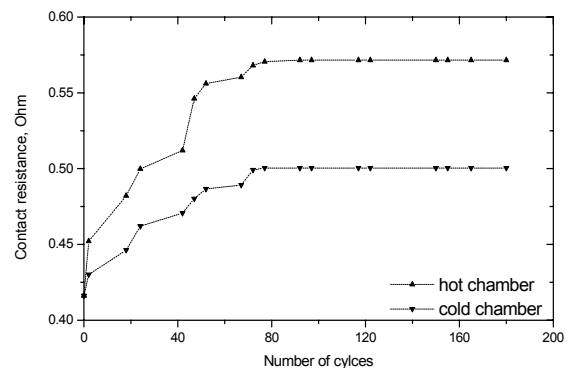


Fig. 6. Variation of online contact resistance with number of cycles at middle pad of chip during thermal cycling profile (140°C to -40°C).

Microstructural analysis was carried out to investigate the extent of damage of the conductive particles at the ACF interconnection after thermal cycling. For this purpose, the sample that suffered the higher thermal warpage was studied. The cross-section of the ACF joint for the assembly without thermal cycling is shown in Figures 7(a) and (b) and for the assembly which experienced a thermal shock in cycling condition of 150°C to -65°C for 100 cycles is shown in Figures 7(c) and (d). From the cross-sectional microstructure, it is clear that conductive particles deformed in different extent with the Al pad and the Au/Ni/Cu pad. Au layer is very thin and Ni is harder than that of the Al. Thus, one side of the particles were en-captured in the Al pad, whereas, in the other side in contact with the Au/Ni/Cu pad, particles were flattened with higher extent of the deformation. In the as-bonded sample, there is a gap in between the pads as shown in Fig. 7(a) and the conductive

particles have a good contact between both input pads as in Fig. 7(b). However, the gap between the chip pad and the substrate pad is filled due to oxidation in Al pad during thermal cycling as shown in Fig. 7(c) and the conductive particle lost the contact with the pad as in Fig. 7(d). The oxide layer formed due to prolonged thermal exposure limits the Chip Al pad and substrate pad to move away from each other when there is a shear stress generated due to warpage in the assembly.

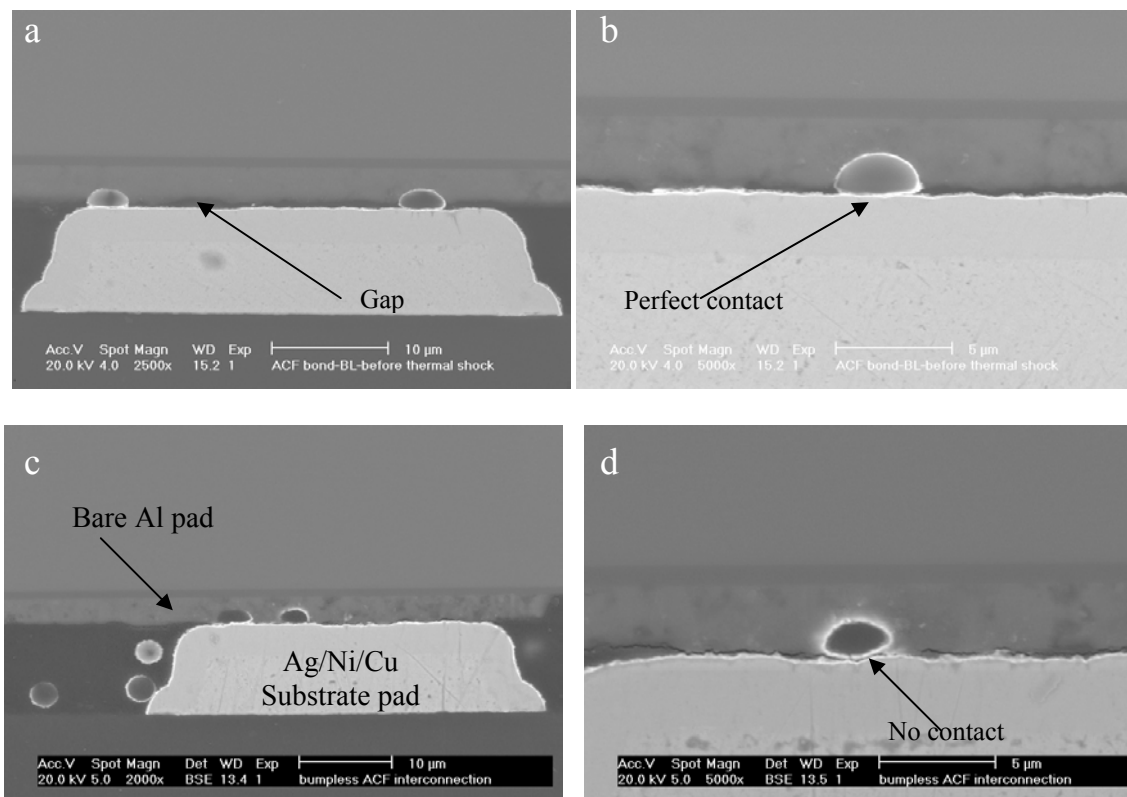


Fig. 7. SEM micrographs showing the ACF interconnections: (a) and (b) sample as bonded; (c) and (d) sample after thermal cycling

Comparing the high temperatures online contact resistance curves from Figures 3, 4 and 5 we can get an idea about contact resistance ramp with number of cycles of testing. The comparison is based on the data taken from the corner

joint of the flip-chip on the flex. As the thermal cycling profile of 125°C to -55°C is below the glass transition temperature (T_g) of the ACF material, the online contact resistance in this profile showed entirely different

characteristics compared to other thermal cycling profiles above (T_g). From comparing the high temperatures curves of Figures 3, 4 and 5, it is clear that the online contact resistance was low for thermal cycling profile 125°C to –55°C compared to other two thermal cycling profiles. Fig.8 shows the differences between hot and cold chamber values for different thermal cycling conditions. Below T_g , ACF is stiff enough to hold the interconnection firmly even at corner positions. However, as 125°C is close to T_g , visco-elastic deformation in the ACF matrix occurs due to the stress generated from the thermal mismatch between the chip and the flex substrate. Thus contact resistance increases, although it is very low compared to other thermal conditions above T_g . During bonding of the assembly, the conductive particle is compressed and an elastic energy is stored up in the particle. However, when the resin is cured the compressed particle tends to regress to its original form thus reducing the contact area of conductive particle. The same phenomenon repeats when temperature exceeds T_g and ACF epoxy loses the stiffness.

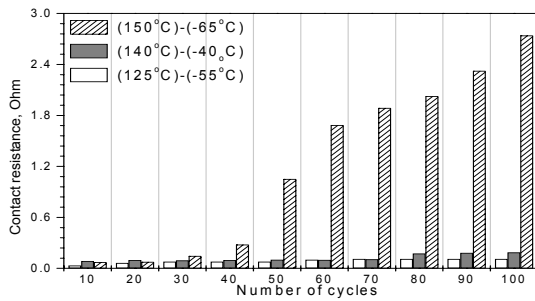


Fig. 8. Contact resistance differences between hot and cold curves for different thermal profiles.

Theoretical shear strain calculated using Equation (1) is shown graphically in Fig.9. The graph reveals that the shear strain increases as the peak temperature increases and the induced shear strain steeply increases after the temperature reaches around the glass transition temperature (T_g) i.e. around 131°C. The stresses caused by thermal loading elongate the chip and substrate to certain limit; however, practically the adhesion strength of ACF holds the chip and substrate firmly.

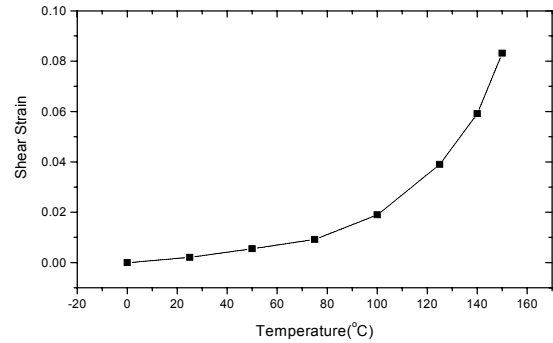


Figure 9. Calculated shear strain on the corner pad on the ACF bumpless flip chip assembly upon thermal loading.

For thermal cycling profile having high temperature above T_g , the ACF becomes less viscous and the conductive particle movement becomes possible in high temperature. However, due to the different thermal expansion co-efficient between the flex and the chip, there would be a thermal stress in the package, which tends to warp the assembly [13]. As the flex has a higher thermal expansion co-efficient than that of chip, it tends to expand and thus the pads of the flex tend to move in X and Y directions from their corresponding pads of the chip [14]. In this study, a rectangle shaped chip was used. Considering elongated side as Y direction of the assembly, the joint at the far end of the Y – direction suffers highest stress to move apart. When the pad slides front and back in Y direction during hot and cold thermal cycling, the conductive particles in the interconnection get damaged, thus causing a contact resistance increase. When the pad moves in the Z direction, the conductive particles relax, thus causing the contact area of the conductive particle with the chip pad and substrate pad to decrease. It limits the area for current flowing through the conductive particles between the pads, which increases the contact resistance. For higher temperature profiles the mismatch is also high. However, the chip used for this study was the bumpless, i.e. only bare Al pads were exposed for interconnection. This bare Al pads are susceptible to oxidation during thermal cycling [15]. Due to the expansion of the volume, the gap between the Al pad and substrate pad reduces and sometimes Al pad touches to the substrate pad. Fig. 7(c) & (d) confirm this finding – thus it decreases the movements between the Al pad and substrate.

This finding also indicates that by increasing the thermal cycling temperature, we can study the extent of thermal mismatch between the pad and flex. Higher thermal cycling

temperature causes compression stress to be relaxed, and making the opposite electrodes disjoin [16]. When the temperature is below the glass transition temperature (T_g) as in the case of thermal profile of 125°C to -55°C, the resistance increase will be lower compared to other thermal cycling profiles. Thermal profiles of 140°C to -40°C and 150°C to -65°C had also many differences between each other. As the temperature in hot chamber increases, the ACF loses its quality and the resistance increase is higher for 150°C to 65°C cycles.

Repeated observations show that after certain time/cycles, the contact resistance increases abruptly during thermal cycling. After this time/cycles, it was found that the online contact resistance in hot chamber increased rapidly and the joints become no longer reliable. The time/cycles taken for this phenomenon to occur is called the incubation time. From the curves in Fig. 3, it is clear that thermal cycling condition of 150°C to -65°C had the incubation time of around 40 cycles and for thermal cycling condition of 140°C to -40°C, the incubation time was around 150 cycles as in Fig. 4. No noticeable incubation period was detected for the thermal cycling condition of 125°C to -55°C within the 500 cycles used for this study. It is proposed that during incubation period, a critical transition occurs in the ACF joint. It happens when the ACF fails to hold Chip Al pad and substrate pad at their original position. The assembly losses its integrity due to the thermal stress generated between chip, ACF and flex substrate. Quite naturally, below T_g of the ACF materials, ACF can maintain its firmness up to prolonged time but it may fail at least at the corner joint.

Thermally induced warpage affects the interconnections throughout the assembly, but the highest online contact resistance was found at the corners of the chip. The corners of the chip had the maximum extent of damage during the thermal shock [17]. Fig. 6 shows the online contact resistance behavior in middle of the chip. There was slight increase in online contact resistance for the joint at the middle compared to the corner for the same thermal profile. Fig. 10 shows the calculated shear strain at different positions of the assembly for three different peak temperatures used for thermal cycling, it is clear from the graph that the induced shear strain directly increases as the distance from middle of the chip. The shear strain at the corners are much more higher than at the centre of the chip. For temperatures above T_g , shear strain is even higher. Fig. 11 shows the variation of the high temperatures contact resistance for middle and corner. The variation in the middle was negligible compared to the corner. When the stiffness of the ACF breaks down at temperatures above T_g , the chip pad and substrate pad slide on each other causing

particle damage. The effect of warpage and dislocation of assembly should be more at the corners. Therefore, the number of conductive particles damaged and/or slipped out of joint was high at the corners. From these results of theoretical analysis, it is understood that the corners suffered more damage in interconnection than in middle of a chip during thermally induced warpage. Repeated shear forces have damaged the conductive particles. The effect of such shear strain is higher at the corner. It is actually proportional to the distance from the middle position, i.e. summing up all the stresses progressively to the end of the chip. From this finding, we can confirm that the longer the chip, the more vulnerable to fail at the corner.

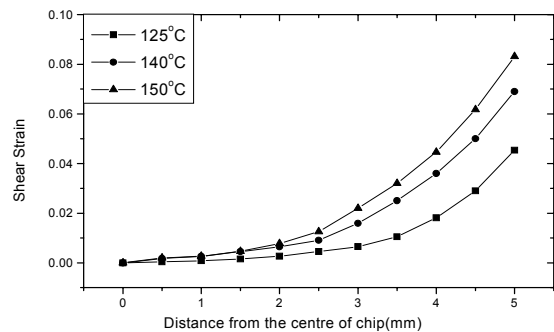


Figure 10. Calculated shear strain range on different positions of the assembly for three different peak temperatures.

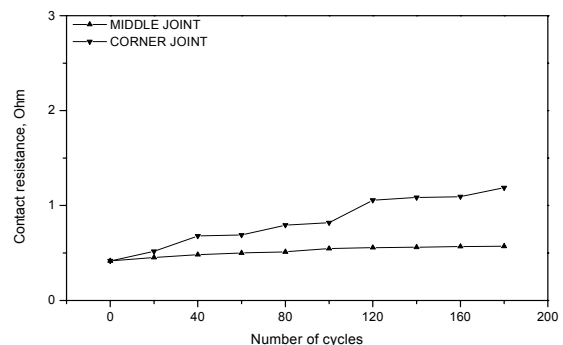


Fig. 11. Differences between the increase in online contact resistance in middle and corner joints.

4. CONCLUSION

The effects of thermal cycling on the online contact resistance of the ACF interconnection for the bumpless chip-on-flex assemblies were studied for three different thermal cycling conditions (125°C to -55°C, 140°C to -40°C and 150°C to -65°C). It was found that for the thermal

cycling profiles having high temperature above the T_g , the ACF expands, and lose its rigidity thus vulnerable to the unbalanced force generated by thermal stresses. Results show that for thermal cycling condition 150°C to -65°C the online contact resistance increased to the maximum of 8.2Ω in 100 cycles. Whereas for thermal cycling condition 125°C to -55°C the online contact resistance increased to 0.9Ω in 500 cycles. It was found that the chip pad and substrate pad move in the opposite direction causing the conductive particles to move and/or damage easily. The incubation time after which the failure is rapid is found earlier for in thermal cycling temperatures above T_g of ACF. Incubation time/cycle occurred at around 40 cycles for thermal cycling condition 150°C to -65°C and 140 cycles for thermal cycling profile 140°C to -40°C. Whereas there was no incubation time noticed for thermal cycling profile 125°C to -55°C. ACF joint loses its rigidity and online contact resistance increases sharply after the incubation time. There were many open joints identified after thermal cycling.

The online contact resistance was also monitored for the joint at the middle position and at the corner position. It is confirmed that the extent of contact resistance increase is higher at the corners of the chip than that of in the middle position. For the thermal cycling condition 140°C to -40°C, the online contact resistance increased up to 1.2Ω in the corner joint and in the middle joint of the chip, the online contact resistance increased only up to 0.5Ω. As the assembly tends to bent due to temperature fluctuation, the extent of warpage is high in the corners, which damage the conductive particles severely due to highest cumulative stress. Thus, the contact area between the Al pad of the chip and the pad of the substrate decreases. It limits the current flow between the I/O of the chip and the substrate pad – thus results in increasing the contact resistance. The contact resistance increase in the middle position was negligible compared to the corners.

Finally, in order to decrease the thermal warpage in the assembly it is recommended to use an ACF with lower CTE and also to use an ACF, which has higher glass transition temperature. It is also vital to select the substrate material having more or less similar CTE of the silicon. From this work, it is recommended to avoid larger chip for ACF joint, as the joint at corner of a long chip is susceptible to fail during thermal cycling.

Acknowledgement

The authors would like to acknowledge the financial support provided by City University of Hong Kong

Research Grant council for project entitled “Reliable packaging of integrated micro-electro mechanical sensors” (City U Project No: 9050178).

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