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EFFECTS OF LOOPING FORMATION ON WIRE SWEEPING PROBLEM OF A NEWLY DEVELOPED QFN PACKAGE

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ABSTRACT

The deflection of gold wire bonds during encapsulation of IC packaging can seriously cause wire crossover and shorting. This paper presents the wire looping formation in affecting the wire sweep in Quad Flat No Lead (QFN) packages. The design of experiment was performed using the 2^k factorial method. Three looping parameters were considered in order to perform nine combinations of looping formations, and these looping parameters are kink height, reverse motion and loop factor. In order to get the most effected factor for wire sweep, the analytical method was applied using the specific statistical software. The results showed the maximum value of kink height and loop factor gave the lowest sweep stiffness. It was also found that the looping formation with higher loop height and wire payout gave the higher readings of wire sweep.

INTRODUCTION

THE wire bonding technology is a momentous interconnection method in chip level packaging for portable and handheld electrical production. As the development of electronics packaging aims to lower cost, increase the packaging density and improve the performance, to drive the bond pad pitch becomes finer and finer is a need. The allowable bond pitch for a typical lateral movement in the direction of the compound flow through the cavity should be greater than the deflection with the consideration of wire diameter to avoid circuit shorting. In the packaging industry, they still work on the use of tests to adjust the bonding parameters to meet the design requirements. This trial-and-error process is inefficiency and cost ineffective, and cannot meet the demand of shorter product cycle [1].

In these stacked die packages, their wire bonds usually possess longer and higher interconnections than conventional individual chip packages. Wire sweep usually denotes visible wire deformation, typically a lateral movement in the direction of the compound flow through the cavity. Wire sweep failure can be caused by any of the following reasons: high resin viscosity, high flow velocity, unbalanced flows in the cavities, void transport, late packing, and filler collision [2].

There have been studies on wire-sweep analysis: Nguyen et al. [3,4] examined the parameters including the material flow properties, the mold cavity/leadframe aspect ratio, the wire modulus, and the wire bond configuration (e.g., diameter, length and

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orientation). However, In this paper, however, the correlation between three looping parameter in affecting the wire sweep deflection. The factors that govern the deflection also be pointed out.

EXPERIMENTAL METHOD

In this study, Quad Flat No-Lead (QFN) stacked die package were used. This package has no lead exposed from the mold so it will make it easy to mount on the printed circuit board and less noise distortion signal. The stacked die has its benefit in multifunction the used of the package. Figure 1 shows the process flow of the QFN and where the wire bond and molding process take their places.

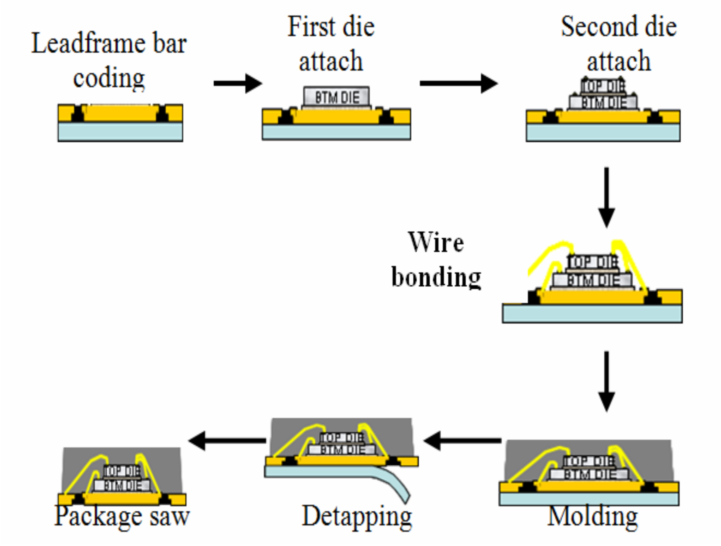

Figure 1: Process flow of a QFN stacked die.

Materials
Gold bonding wire is normally specified as 99.99% (4-9’s) purity, while chemistry the residual 100 ppm is carefully controlled to provide the required mechanical and electrical properties. The diameter of the wire is 0.0254 mm (1mils). The mechanical properties for this wire type are listed in Table 1:

Table 1: Mechanical properties for the 25.4 μm wire [5].

Mechanical properties	*Value*
Breaking load (mN)	98.0 ~ 157.0
Elongation (%)	2.0 ~ 7.0

Looping Parameters
There are few parameters for looping parameters in wire bonding machine (Figure 2) that effect looping height but in this study three parameters were considered, i. e.:

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a) Kink height - Defines the vertical distance that the capillary rises above the ball bond before the capillary is moved in X/Y direction. Sets the height above the ball before moving the reverse motion. The kink height, in combination with the reverse motion distance will give the loop height above the ball.
b) Reverse motion - Defines the horizontal distance that the capillary moves in the opposite direction to that of the wedge bond. This is a programmed motion that will support the kink height to produce the loop height above the ball
c) Loop factor - This parameter is used to correct the wire payout from that calculated by software. Start with a zero value before optimization

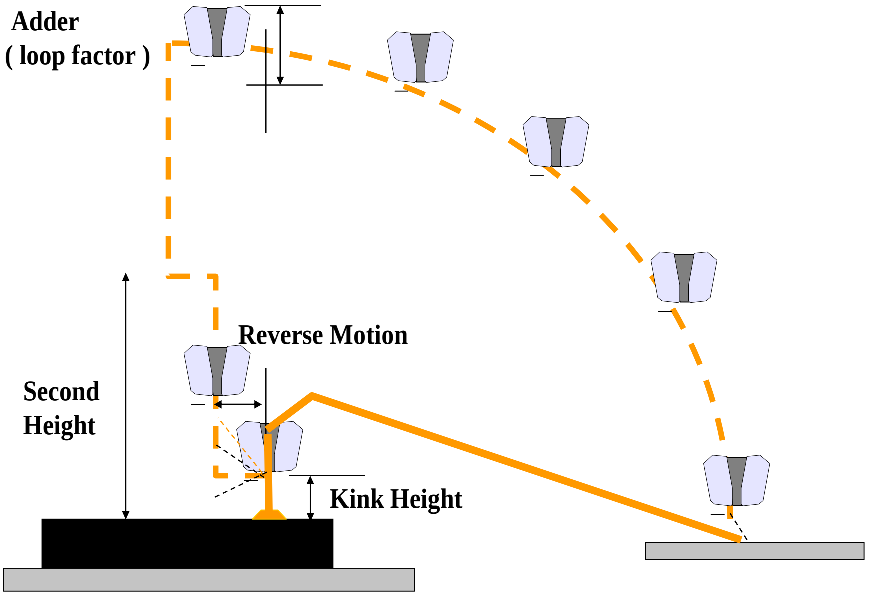

Figure 2: Looping parameters [2].

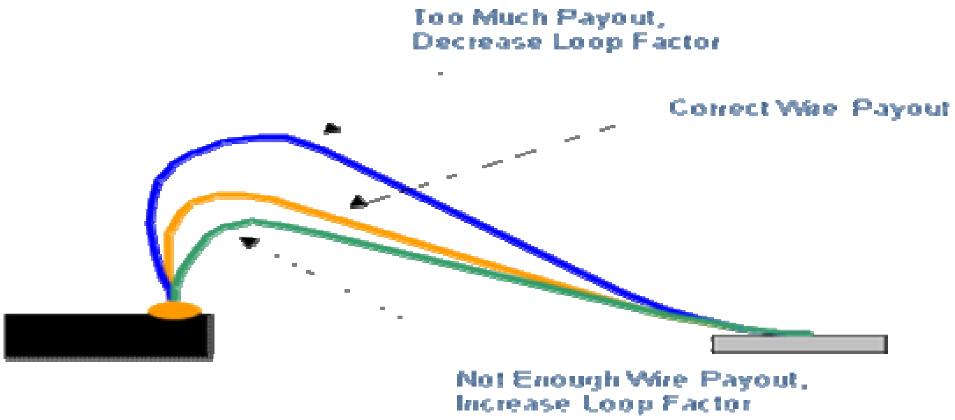

Figure 3: Looping formation controlled by loop factor [2].

The listed three factors give a significant effect for the wire looping formation. The kink height and reverse motion effect the necking formation and loop factor which contribute in the payout wire. In order to show a diagrammatically understanding of this situation, Figure 3 shows the looping formations of the wire controlled by the loop factor.

Methodology

The 2^k design is particularly useful in the early stages of experimental work, when there are likely to be many factors to be investigated. It provides the smallest number runs with *k* factors can be studied in a complete factorial design. Consequently, these designs are widely used in factors screening experiment for the industries [6]. In this study, the 2^k factorial experimental designs was used to observed the effect of three selected factors on the wire pull test. The using of this design can reduce cost and time to run the experiment because the factors can be chosen that give the main effect to the response.

The design of experiment using fractional factorial design is carried out in order to observe the looping formation of wire based on the combination of the factors. Table 2 shows the design of experiment with nine combinations of looping parameter values.

Table 2: Design of experiment the using 2^k factorial approach.

Run	Factors		
	Kink Height	Reverse Motion	Loop Factor
initial	6	4	-3.5
1	5 (-)	2 (-)	-5 (-)
2	5 (-)	2 (-)	-2 (+)
3	5 (-)	6 (+)	-5 (-)
4	5 (-)	6 (+)	-2 (+)
5	7 (+)	2 (-)	-5 (-)
6	7 (+)	2 (-)	-2 (+)
7	7 (+)	6 (+)	-5 (-)
8	7 (+)	6 (+)	-2 (+)

(-) = the minimum value (+) = the maximum value

The measurements of every point along the wire using Hisomet were performed (Figure 4) and plotted to observe the looping formation of the wire. Hisomet is used to measure the height of the package in semiconductor industries. The Hisomet is a non-contact depth measuring microscope that has been designed based on the optical focal point detection system. The precise focus indicator is adopted, so that the measurements of height, depth, steps, etc. are made possible simply by coinciding the two halves of an index graticule while observing the surface of a point of measurement.

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The percentages of deflection wire were also measured using TOSMICRON X-ray machine. The data then have been analyzed using MINITAB in order to study the correlation between factors on affecting the wire sweep. Studies also concluded the others factors that contributed to the wire sweep.

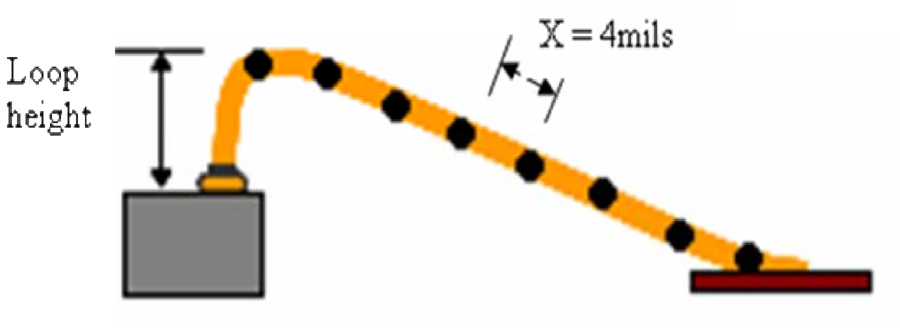

Figure 4: Loop height measurements for every point.

RESULTS AND DISCUSSION

Figure 5 shows the result for loop height and run 6 and 8 have the highest loop compared to other run. The measurement results using the X-ray machine showed the wire deflection usually happened for bonded wire which is located at the edge of the silicon die (Figure 6). It was also because of the wire length i.e. the longest wire length was located it this position.

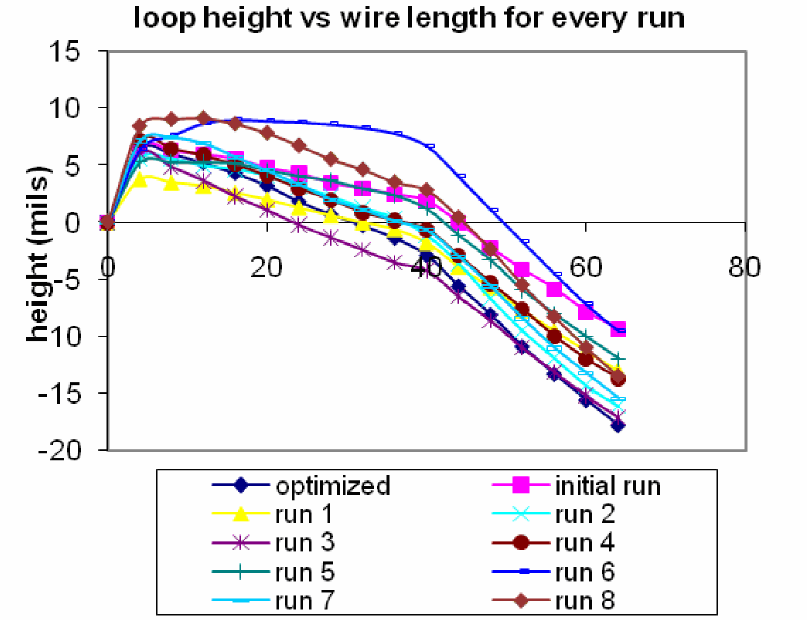

Figure 5: Looping formations for different combinations of looping parameter.

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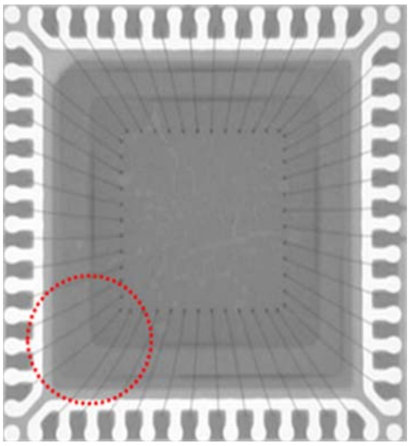

Figure 6: X-ray image.

From the analytical results, it was observed that the loop factor was identified as the factor which gave the major effect to the wire sweep issue, as presented in the plot of Figure 7. This situation was happened because of too much wire payout to make the formation unstable and it can also caused the sweeping of the wire. The analyzed data also showed these three factors were significantly governed by the deflection of the wire.

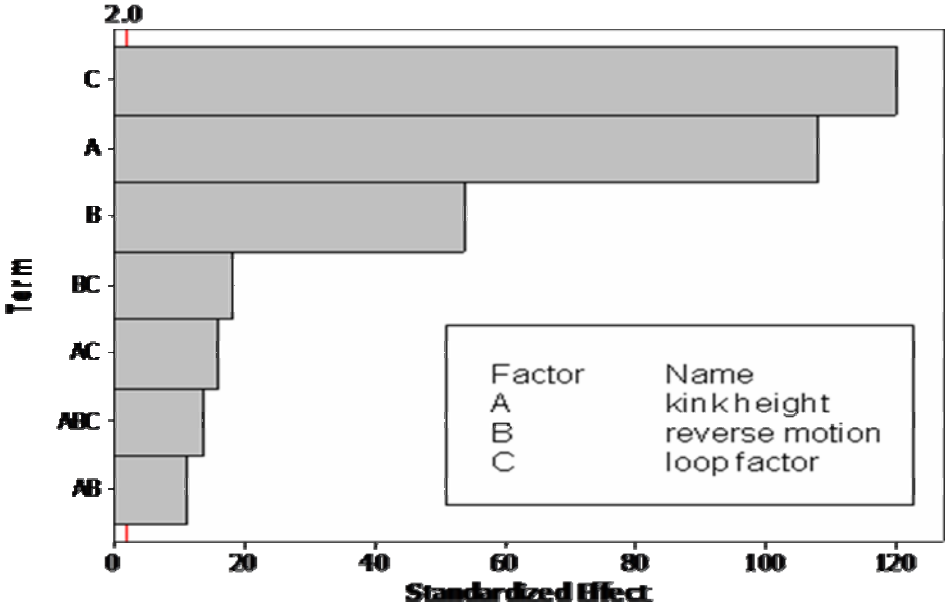

Figure 7: Pareto chart of the standardize effects.

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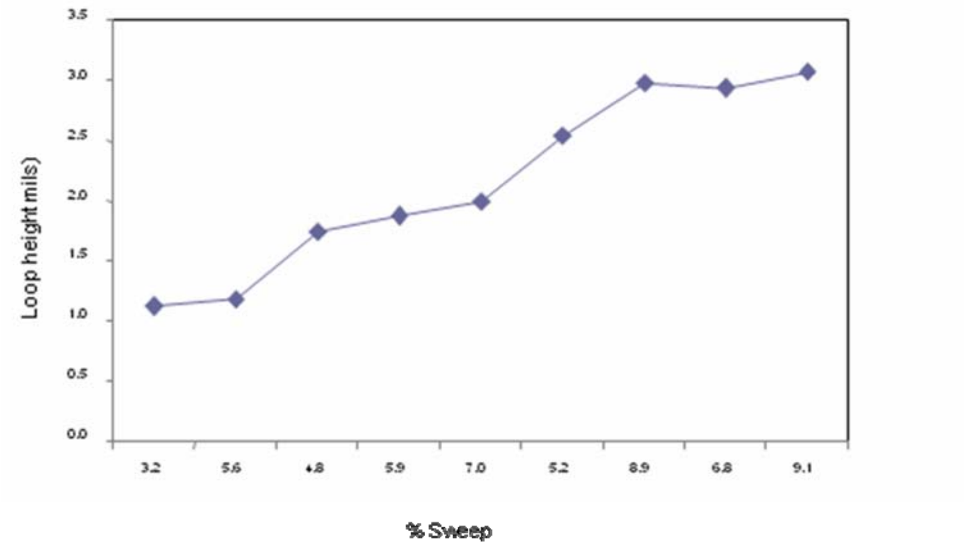

Figure 8: The percentage of wire sweep for different loop height.

Theoretically, the percentage of wire sweep also depends on the loop height of the looping position. In order to assist the designer of bond profile for obtaining the reasonable allowed wire sweep, a sweep deflection model based on the contributions of the bending moment and the twisting moment was proposed by the literature. According to the model, the sweep deflection of wire bond can be mathematically defined as the following expression [8]:

$$\frac{\delta}{S * p} = f_B \frac{H^3}{EI} + f_T \frac{L^3}{GJ} \qquad (1)$$

where δ is the sweep deflection of wire bond, S is the bond length, p is the drag force per unit length of wire bond, E is the elastic modulus of wire bond, G is the shear modulus of wire bond, I is the moment of inertia, J is the polar moment of inertia, H is the loop height, L is the bond span, f_B is the bending geometry factor for the bending moment, f_T is the twisting geometry factor for the twisting moment. From this equation, the loop height is automatically increased with the decrement of wire deflection. This condition can be extracted from the result of Figure 8.

CONCLUSION

From the result, it can be concluded that loop height measurement can be performed by using HISOMET. Each run gave the different loop shape according to the different value of kink height, reverse motion and loop factor. X-ray machine can be used to measure wire sweep. Different loop shape gave different wire sweep reading due to the loop height and wire pay out. Statistical method using Pareto chart was applied to obtain the most significant factor that affected wire sweep. Therefore, this method was useful in order to face the flexibility of wire bonding enables the successful use of new packaging technologies such as stacked die packages.

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