Solid State Science and Technology, Vol. 16, No 2 (2008) 232-239
ISSN 0128-7389

GOLD WIRE NECK STRENGTH ON DIFFERENT COMBINATIONS OF LOOPING PARAMETERS

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ABSTRACT

The movement of the wire capillary is controlled by looping parameters that will generate the wire bending, compressive and tensile stresses that will cause necking problem. The wire looping parameters that affect the wire loop formation, especially at the neck area were studied in this paper. The wires were bond with different kink height, reverse motion and loop factor using thermosonic technique. Design of experiment using the 2^k factorial was applied and performed nine combinations of looping formations. Before molding process, the units were observed using Scanning Electron Microscopy (SEM). The wire pull test experimental results are carried out in order to check the strength of the neck and analyzed using the statistical method. The results shown that run 1 gave the lowest wire pull reading, that is 84.847 mN, compare to other runs. Run 1 has the lowest wire pull reading because it formed the lowest loop height that affected the neck strength in becoming weaker. Moreover, statistical method using main effect plot applied to observe the trend of neck strength due to the value of looping parameter.

INTRODUCTION

In recent years, as integrated circuit packaging development has moved towards higher power, smaller size, thinner dimensions, denser circuits and higher reliability, wire bonding is still the most commonly used bonding interconnection technique in first level microelectronic packages [1]. In this interconnection method, bonding wires carry power and signals between the active semiconductor circuits and the lead frame or substrate metallization.

The critical issues in the fine pitch wire bonding are designing a prescribed trajectory for the capillary so that each wire can meet the packaging configuration constraints as well as to keep the loop height at the lower level in order to avoid the wire sweeping problem. Low loop height will cause the problem such as broken neck. It is important to fully understand the dynamic characteristics of the wire looping process to develop better design tools to quickly obtain an optimum loop profile.

The wire bonding is performed using thermosonic technique. Ball bonding is the process in which pads are connected onto a die and leadframe (or substrate) using very fine diameter wire. The basic steps of ball bonding include the formation of:

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the first bond (normally on the chip), the wire loop, and the second bond (normally on the substrate). The wire-bonding cycle is shown in Figure 1 [2].

At the beginning of the wire cycle, the bonding tool travels down to the first bond location (Steps 1 and 2). The first bond is achieved by bonding a spherical ball to the pad using thermal and ultrasonic energy (Step 3). The initial bond is also referred to as the ball bond. Looping motions are programmed to meet the package requirement for loop height and shape (Steps 4, 5, and 6). The second bond consists of a stitch bond that bonds the opposite end of the wire and a tail bond (Step 7). The tail bond is needed to form a wire tail for the next ball formation. After the bonding tool rises to pay out the wire tail, the tail is broken off and the bonding tool rises up to the ball formation height (Steps 8, 9, and 10) [2].

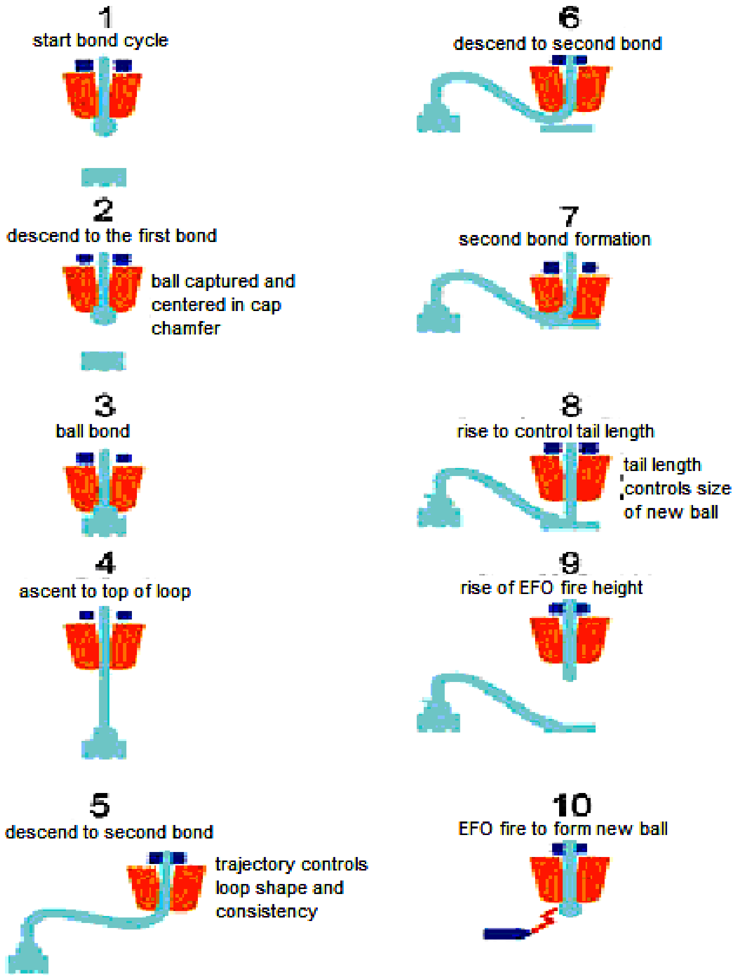

Figure 1: Ball bonding steps [2].

The point where the wire is bent called neck. This region has a critical structure called heat affect zone (HAZ). When the ball is formed by proper ball forming condition, wire is inevitably affected by heat. This is because the ball part fully

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melts during ball formation, so the boundary which is affected and non-affected range formed.

Many studies were previously performed in order to get the good condition of looping formation using statistical methods. This related statistical analysis evaluated the main effects and bonding parameter interactions on loop profile characterization using a method, called response surface methodology (RSM). In addition, this method is also useful to study the material properties for wire [4-6]. This paper investigates the effects of looping parameter on looping formation. The wire neck strength was measured as it is the main subject of this paper.

MATERIALS AND METHODOLOGY

In this paper, the necking analysis was conducted on Quad Flat No-Lead (QFN) stacked die packages. 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.

Materials

Gold bonding wire is normally specified as 99.99% (4-9's) purity, with chemical residual 100 ppm carefully controlled to provide the required mechanical and electrical properties. The diameter of the wire is 0.0254 mm (1 mils). The mechanical properties for the 25.4 µm wire type are listed in Table 1:

Table 1: Mechanical properties for the 25.4 µm Aurum 99.99% (4N) wire [5].

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

Looping Parameters

There are many parameters for looping parameters in wire bonding machine that affect looping height but in this study three parameters were considered. There are as follows:

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 supports the kink height to produce the loop height above the ball (Figure 2).

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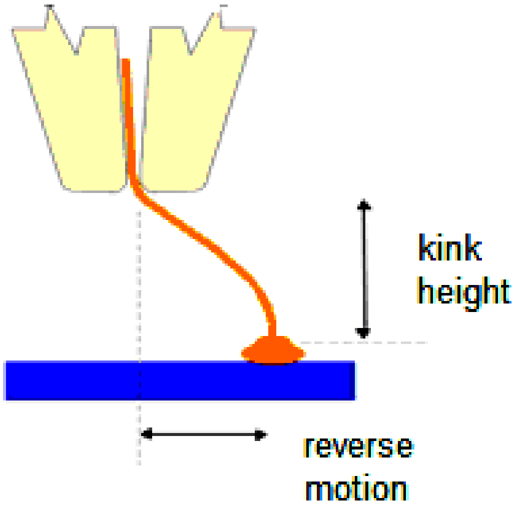

Figure 2: The capillary direction for kink height and reverse motion [2].

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 3).

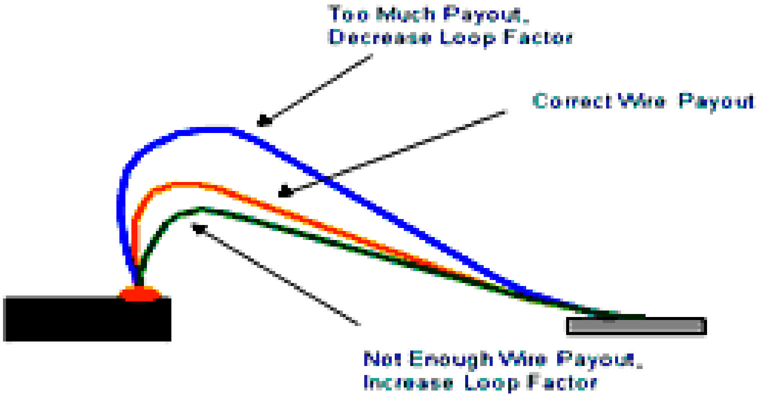

Figure 3: Loop factor control [2].

Methodology

The 2^k factorial 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 that runs with *k* factors can be studied in a complete factorial design [6]. Consequently, these designs are widely used in factors screening experiment for the industries. In this study, the 2^k factorial experimental design was used to observed the effect of three selected factors on the wire pull test.

The design of experiment using fractional factorial design was performed in order to observe the looping formation of wire according to the combination of the factors. Table 2 shows the design of experiment with nine combinations of looping

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parameter values.

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

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

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

The observations using Scanning Electron Microscopy (SEM) was also performed in this paper. Then the samples were tested in terms of wire pull strength by using XYZ Condo machine. The collected data were then analyzed using statistical software (MINITAB 15).

RESULTS AND DISCUSSION

Scanning electron microscopy (SEM) technique was used to observe the neck formation of the wire. In Figure 4, shape of the loops is decreased when loop factor is switched from the minimum value (-) to the maximum value (+).

Although the neck formation did not show the broken wire, the strength at the wire was different because some wire formations were in tight condition especially when the combination parameters were in minimum value. Figure 5 shows the reading of wire pull test for every run. From this graph, the lowest loop shape gives the lowest readings of pull test because the stress at the wire is high and the grain structure at that area is weaker compared to other runs.

The purpose of data analyzing using the statistical software is to determine the main effect plots (data means) for wire pull readings. Figure 6 shows that the wire strength increased when all the factors increased.

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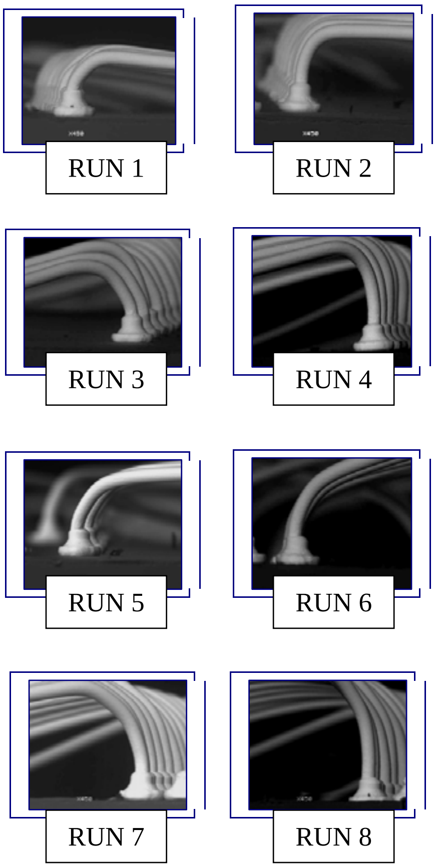
RUN 1
RUN 2
RUN 3
RUN 4
RUN 5
RUN 6
RUN 7
RUN 8

Figure 4: Neck formations for every run.

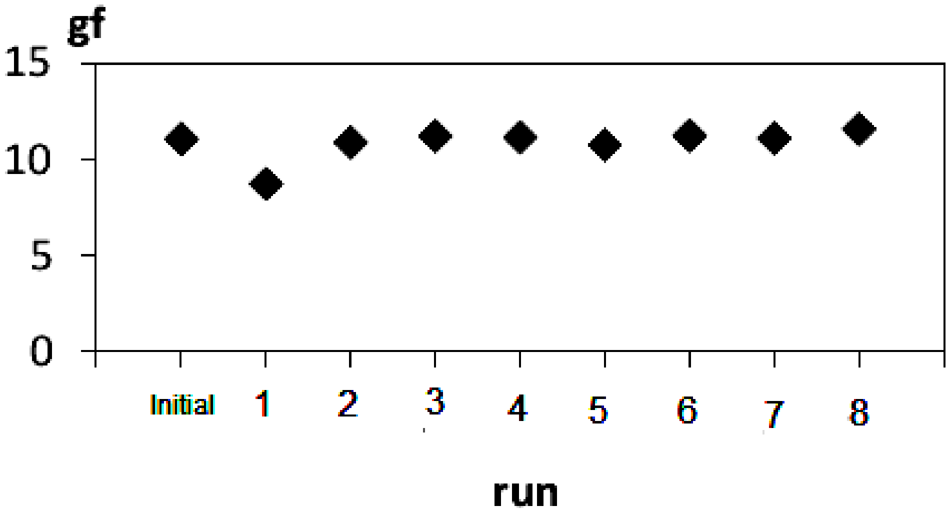

Figure 5: Wire pull test reading for every run.

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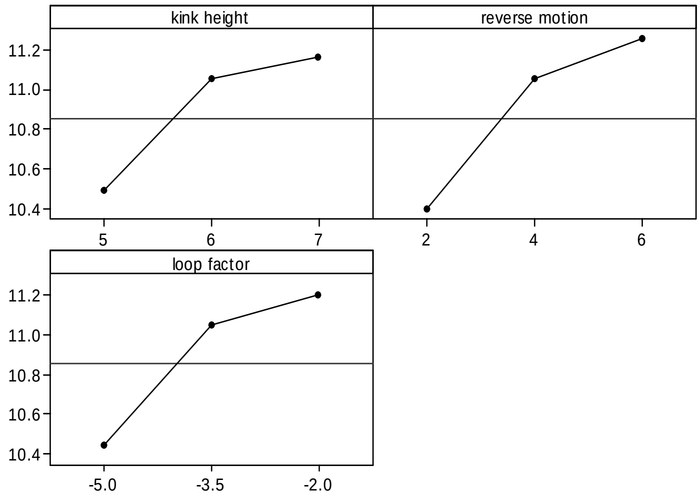

Figure 6: Main effect plots (data means) for wire pull.

CONCLUSION

The looping parameters influence to the loop shape and wire strength. Kink height, reverse motion and loop factor are the main factors in designing the different type of looping. Low loop can affect wire neck strength due to the fact that at the neck of the wire, it shall induce more stress. Therefore the wire pull reading becomes lower at that point. All the factors can produce many shapes of wire loop in stacked die package in order to increase the footprint and functionality of semiconductor devices. Therefore, the new packaging types required more complicated looping configurations ahead.

ACKNOWLEDGEMENT

The authors would like to thank the Malaysian Ministry of Science, Technology and Innovations for sponsoring this work under project IRPA 03-01-01-0088-PR0075/09-08 and AIC Semiconductor Sdn. Bhd., Kulim Hi-Tech, Kedah in providing experimental facilities.

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