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EFFECTS OF USG CURRENT AND BONDING LOAD ON BONDING FORMATION IN QFN STACKED DIE PACKAGE

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ABSTRACT

Gold is commonly used as bonding wire that connects the die bond pad and substrate. Bond power and bond force are the main factors during wire bonding process in order to get the robust ball bonding. The objective of this investigation is to determine the effect of power and force on bonding process for 99.99% gold wire for wire type A and B in Quad Flat No-Lead (QFN) 3D stacked-die packages. Both wires with diameter of 25.4 µm and bonding temperature of 200ºC were used. The ultrasonic current or USG current was in the range of 70 mA to 90 mA while bonding load in the range of 15 g to 45 g. The result from scanning electron microscope (SEM) shows the ball bonding formation effect by different variation of power and force. The lower bonding load (15 g) give good ball bonding shape as compared to higher bonding load (45 g) for the same USG current and wire type. Bonding load is considered as critical factor as compared to USG current and wire type.

INTRODUCTION

Wire bonding technique is the most widely technology in the microelectronic industry as a definition of interconnecting IC chip and substrate. The interconnections to ≥95% of semiconductor chips are ultrasonically welded in some manner [1]. A variety of investigations [2, 3] have been carried out to reveal the effects of process parameters, such as ultrasonic power, bonding load, bonding time, and bondability. Wire bonding cycle started with electrical breakdown of the air gap between the wire and wand followed by the discharge which heated and melted the tail of wire. Surface tension causes the melted part to roll up into a ball and the ball would then be pressed to form a ball bond. Wire bonding technique has been introduced in 1950s, rapidly develops and fits well the industrial requirements. The wire ball bonder uses an Electric Flame Off (EFO) unit connecting with high voltage to create a Free Air Ball (FAB). During operation, the EFO gap was breached by a high current to create a high voltage spark that melt the tail of the metal wire in a glow discharge to form a spherical ball. The capillary presses the ball onto the bond pad to make a ball bond by applying ultrasonic power and thermal energy. After the ball is bond, the capillary rises to the loop height position while wire is fed out through the end of the capillary. The capillary next travels to the leadframe forming a loop of wire between the chip and leadframe and squashed the wire against the frame to produce wedge bond. After

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the wedge bond is made, the capillary is raised and the wire is torn off from the bond. The next cycle will then start with an EFO firing [4]. A typical wire bonding cycle is shown in Figure 1.

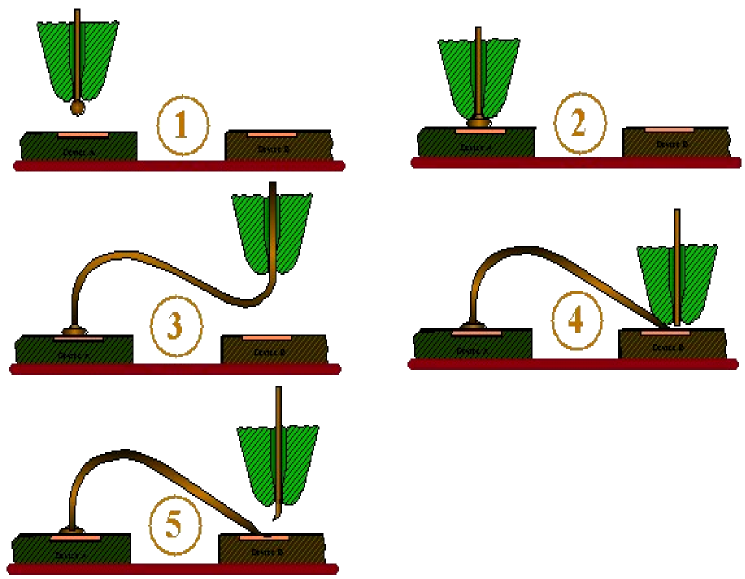

Figure 1: Schematic of the ball bonding process.

METHODOLOGY

Table 1: The description of wire bonding requirement process.

Package Description	QFN Stacked Die 48 Leads				
Case	1	2	3	4	5
USG current (mA)	70	50	50	90	90
Bonding load (g)	30	15	45	15	45
Wire Type	25.4 µm Wire type A and B				

The silicon wafers with aluminum thin film were cut into dies and attached to silver-plated copper based lead frame using a silver loaded epoxy paste. The dies with different sizes

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were attached at the top of the first die. Two types of 4 N gold wire, wire A and B with diameter of 25.4 μm were used and the bonding temperature was maintained at 200ºC. Samples were bonded using K&S Maxum Elite wire bonder. The bonding parameters were set at bond time of 15 ms, USG current in the range of 50-90 mA and bonding load in the range of 15-50 g. The description of wire bonding requirement process is shown in Table 1. Measurements of the ball size and ball thickness are done with Hisomet, a measurement microscope with XY encoders and 400X magnification. EYZTEC Condor tester was conducted to determine the ball shear test while SEM was used to observe the structure of the ball bond.

RESULTS AND DISCUSSION

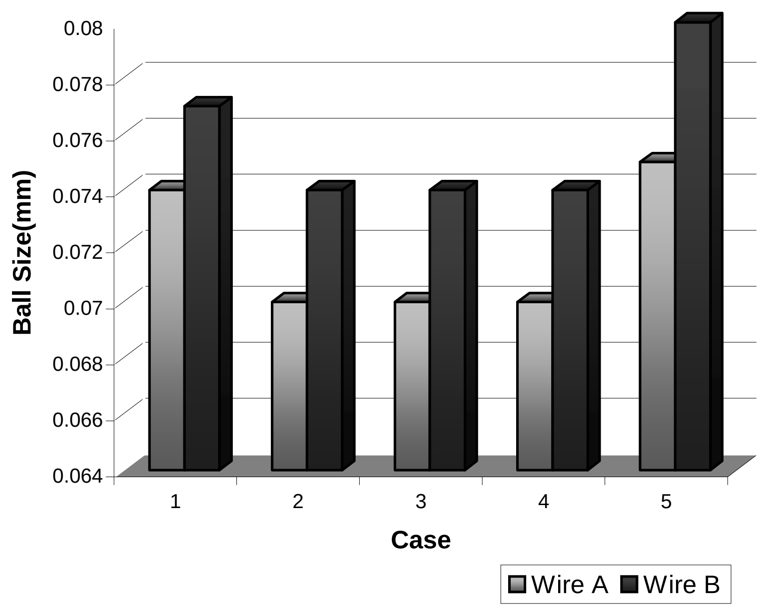

Figure 2: Ball size between wires A and B with different combination of USG current and bonding load.

Figure 2 shows the ball size of two types of wire; wire A and B. For every case, ball size of wire B was higher than ball size of wire A. Increase in USG current often necessitates increase in bonding load to allow proper coupling of ultrasonic energy from the bonding tool to the wire and substrate. This shows that the ball size is controlled by combination of USG current and bonding load because both parameters are interdependent [7]. According to the standard in manufacturing, ball size for gold wire of diameter is 25.4 μm in the range of 0.05 mm -0.08 mm. In this study, there are no significant differences between the two types of wire.

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Figure 3 shows that the ball thickness decreases with increasing of USG current for both wires in case 4 and case 5. A high percentage of smashed bond were observed in both of the cases because of the high current. Beside that, the ball thickness in all cases gave no significant differences between two types of wire.

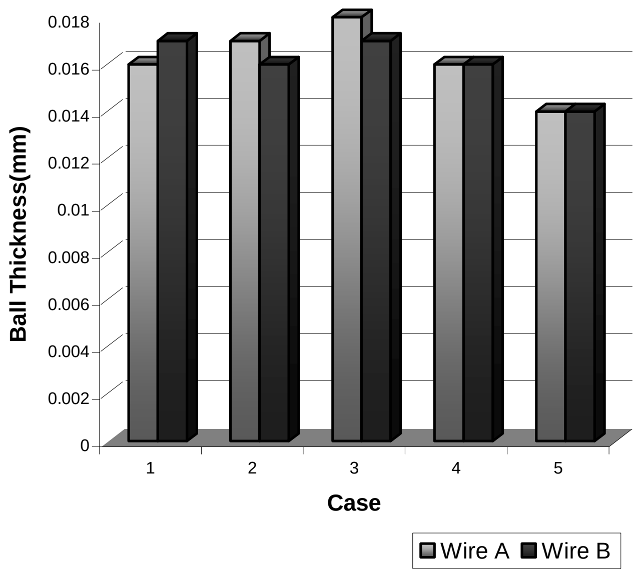

Figure 3: Ball thickness between wires A and B with different combination of USG current and bonding load.

From the histogram, case 4 and case 5 show that a larger ball should have higher shear strength. Maximum shear strength is in case 5 followed by case 1. USG current is an important factor to determine the quality of the ball bond. Shear speed and shear distance also must be optimized for best result and monitoring the quality of the wire bond process [5,6]. However, USG current has the strongest influence on bond quality and visual appearance because it controls the extent of softening of the bonding wire [7].

Figure 5 shows visual techniques used to ensure the proper balls have been formed and verify the bonds are properly placed with respect at the target. It's also screen possible bond defects that may result to an open or short based on the specified defined criteria of wire clearance and close proximity of each bond to the other. Therefore, Figure 5(c) looks more consistent compared to others. This is because the USG current helps to disburse contaminates during the early part of the bonding cycle and helps to mature the weld in combination with the thermal aging.

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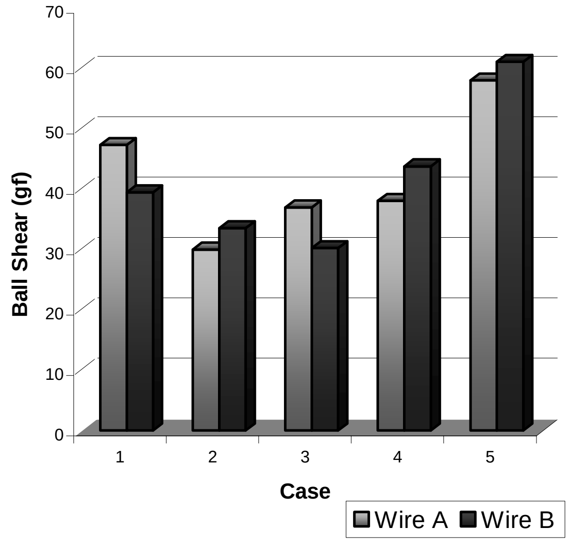

Figure 4: Ball shear data for 5 case with different wire type and different combination of USG current and bonding load.

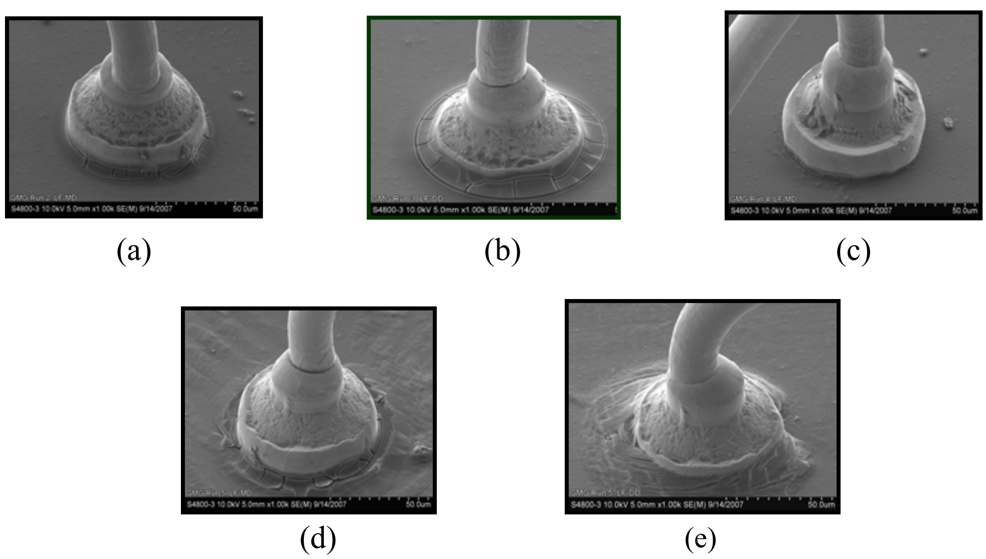

Figure 5: Ball formations from side view for wire A.

The ball bond shape is affected by different variations of USG ball bonds current and load. In Figure 5(b) and 5(e) the are critically smashed and the thickness are slightly lower compared to Figure 5(a) and 5(d). Figure 5(b) shows the ball bond become smashed and the

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thickness are slightly lower compared to Figure 5(c) because thought the USG current was essentially same, which is 50mA, but the bonding loads are different. Excessive bond deformation can occur if either the ball bonding is not properly secured or if the bonding load applied to the bonding tool is too light.

The bonding load obviously affects the bond shape through visual analysis as shown in Figure 6. From above findings, ball bond shape formed is not much different between both types A and B gold wires. Ball bond becomes critically smashed and the thickness is slightly lower. After review another 4 cases, ball bond shape for case 3 showed perfect and smooth surface but others are in control. Figure 6 shows the increase in USG current usually will increase the bonded ball diameter, lowers its thickness and may cause unacceptable squash which had been discussed above. The difference is caused by the different assembly machines and process condition used [7].

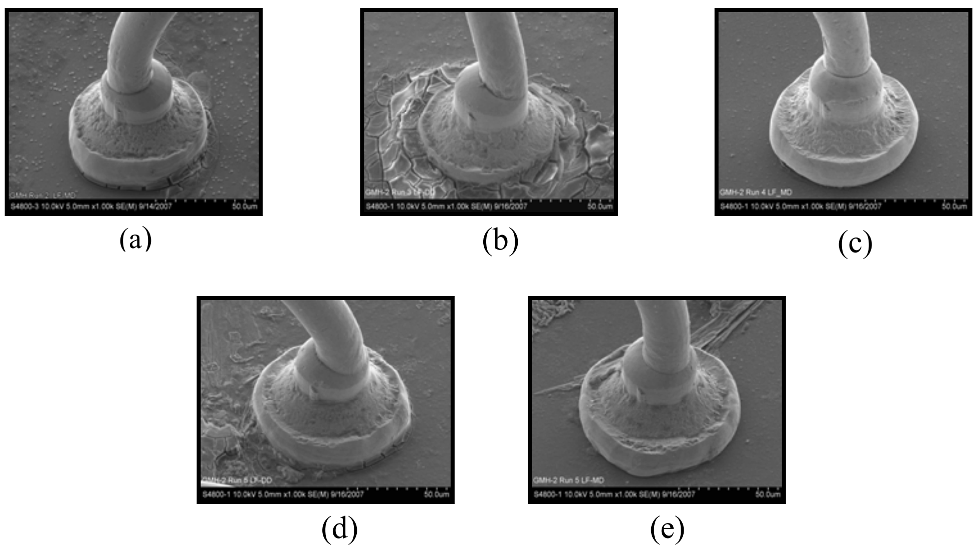

Figure 6: Ball formation from side view for wire B.

CONCLUSION

The effects of USG current and bonding load on bondability and bond pattern in ultrasonic gold ball bonding were studied. The measurement of physical inspection showed there is not much differences between both A and B wires. The lower bonding load (15 g) gives good ball bonding shape as compared to higher bonding load (45 g) for the same USG current and wire type. The bonding load plays important role in obtaining good bonding shape as compared to USG current and wire type.

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