

Experimental Study of EFO Ward Electrode Wear, Surface Pollution, and Discharge Gaps in Wire Bonding Process

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Abstract

In the latest generation of wire bonders, the bond cycle is so short that the ward electrode of the electronic flame off (EFO) discharge used to heat and melt the wire is fixed to side. Because no more than a few ppm defects in ball bonds can be tolerated, any tiny factor such as the EFO ward electrode wear and surface pollution which effect the ball formation will be concerned. In this paper, the EFO ward electrodes of different wear rates and surface pollution were set up to wire bonder and then performed bonding processes. Two typical methods, wire pull and ball shear tests, were used to judge the wire bonding quality. From the experimental results, wire bonding quality descend when the EFO ward electrode wore and surface was polluted. The lowest wire pull and ball shear value have approached to actual production lines standards, and some even lower than specification. It is concluded if EFO ward electrode wear is controlled by adjusting discharge gap and cleaning the surface of electrode regularly, wire bonding quality will not get worse. Therefore a multi-function detectable tool is successfully designed not only to check up the wear and lifetime of electrode, but also to clean its surface. The solution was lately executed in actual production lines, and had been proved effectively.

Key Words: EFO Ward Electrode, Wire Bonding, Wire Pull and Ball Shear Tests, Wear, Surface Pollution

1. Introduction

Wire bonding in semiconductor chip assembly and packaging is most effectively done by ball-wedge bonding [1]. In the latest generation of wire bonders, the bond cycle is so short that the ward electrode of the electronic flame off (EFO) discharge used to heat and melt the wire is fixed to side.

The setup of the device and the bonding cycle are shown in Figure 1 [2]. The bonding cycle commences with wire to ward breakdown followed by the discharge, which heats and melts the wire (Figure 1(a)). Surface tension causes the melted

part to roll up into a ball (Figure 1(b)) and the capillary presses the ball onto the bond pad to make a ball bond (Figure 1(c)). After the ball is bonded, the capillary rises to the loop height position (Figure 1(d)) and travels to the lead frame while wire is fed out through the end of capillary forming a loop of wire between the chip and lead frame. The capillary next squashes the wire against the frame to produce the wedge bond (Figure 1(e)). After the wedge bond is made, the capillary rises and the wire is torn off from the bond (Figure (f)). The typical "golden ball" manufactured by actual production lines is showed in Figure 2.

The wire end is often bent towards one side after the wedge bond. To form the next ball, the EFO discharge must be able to fire from the tip of electrode to the bent wire. Because no more than a few ppm defects in ball bonds can be tolerated, any tiny factor, which effects the ball formation, will be concerned and carefully treated. In present production line, the EFO ward electrode is replaced until it can't "fire." In fact, however, the EFO ward electrode wears as working, and involves inevitable pollution on its surface. It got less attention in these issues if the EFO ward electrode's wear and pollution affect the wire bonding quality. In this paper, the EFO ward electrodes of various wear rates and surface pollution were set up to wire bonder and then bonding. Two typical methods, wire pull and ball shear tests, were used to evaluate the wire bonding quality. In addition, the various discharge gaps caused by electrode wear, showed in Figure 3, were also studied simultaneously.

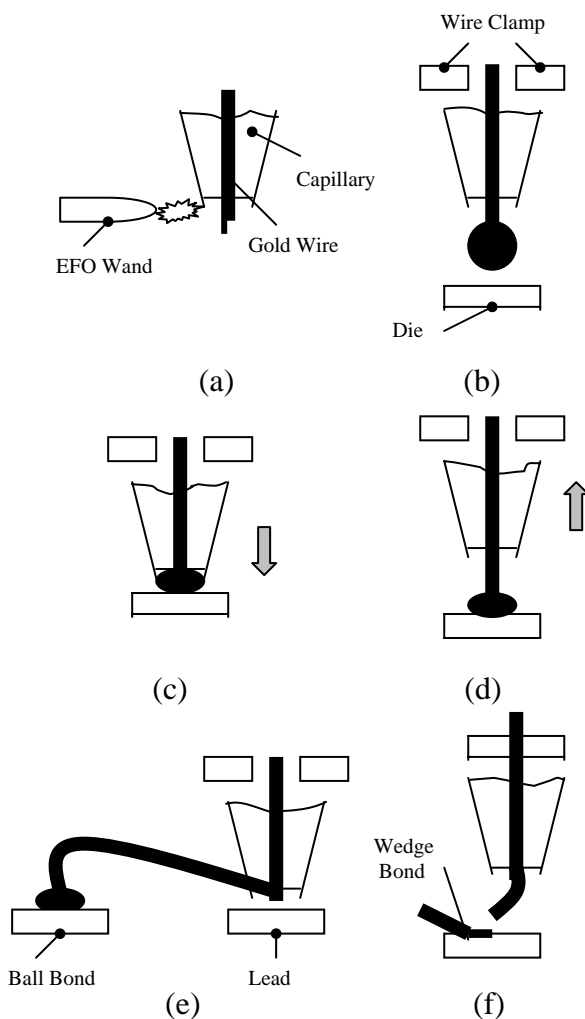


Figure 1. Schematic of the fixed ward design and the wire bonding cycle



Figure 2. The SEM photograph of a golden ball

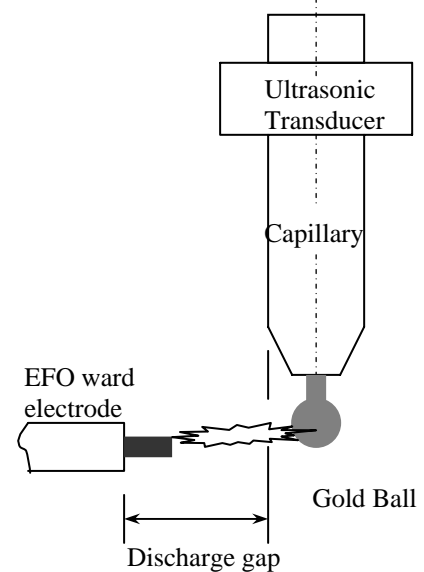


Figure 3. Schematic of the discharge gap

2. Experimental

- Experimental Conditions: a wire ball bonder, a piece of golden wire (diameter 1.2 mil), some Pt (Platinum) EFO ward electrodes and 28 pins skinny P-DIP ink dies were used to do all of experiments. The experimental conditions and the main parameters of wire bonding are shown in Table 1.
- EFO Ward Electrode Wear Experiment: the 0%, 40% and 80% wear rate electrodes are shown in Figure 4. They were set up to wire bonder respectively, and performed bonding processes in the same standard discharge gap (10 mil) and the same major parameters such as bond time, power and force, etc. After bonding, the wire pull and ball shear tests are performed, and then their average and Cpk (Capacity of Process) are calculated respectively.
- Electrode Surface Pollution Experiment: two electrodes of the same wear rate, one of which

removed surface pollution by Acetone but kept on another, were set up to wire bonder respectively, and performed bonding processes in the same standard discharge gap (10 mil) and the same major parameters. After bonding, the wire pull and ball shear tests were performed, and then their average and Cpk were calculated respectively.

- (d) Discharge Gap Experiment: a EFO ward electrode was set up to wire bonder, and performed bonding processes in the same main parameters but different discharge gaps (10 mil and 35 mil). After bonding, the wire pull and die shear tests were performed, and then their average and Cpk were calculated respectively.

Table 1. The experimental conditions and main parameters

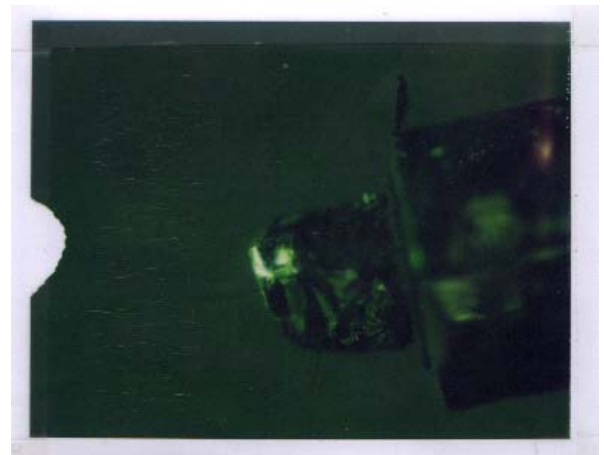
Experimental Conditions	
Wire Bonder	K&S 1484 XQ
Golden Wire Dia.	1.2 mil (T1)
Capillary Type	M-S 41490-0013-334
Ink Dies	28 Ski. P-DIP
Wire Bonding Main Parameters	
Tip Offset 1/2 (1st, 2nd)	75 50
Bond velocity 1/2(1st, 2nd)	4 6
Bond Time 1/2 (1st, 2nd)	15 20
Bond Power 1/2 (1st, 2nd)	45 105
Bond Force 1/2 (1st, 2nd)	35 100
Power Profile 1/2(1st, 2nd)	0 0
Kink Height	55
Reverse Loop	125
Loop Factor	155
EFO gap	10
Loop Trajectory	5
Bond Throttle	95
Ball Size Ratio	1.6
Wire Size	1.18
Contact Threshold	35
Loop factor 2	10
Pre Heat Temp.	200 °C
Heat Temp.	230 °C



New electrode



40% wear



80% wear

Figure 4. The photographs of different wear rate EFO ward electrodes

3. Results and Discussion

Figure 5 presents the influences of different wear rate electrodes on the ball shear, wire pull strength, and its Cpk. When the wear rate increases, the average of ball shear and wire pull value decrease, and Cpk as well. In theory, there are the same strength of every bonded ball and wire because of the uniform EFO discharge emitted by electrode. In reality, however, the various shapes on the electrode tip, due to the “natural wear,” make the electrical field unstable and tend to decay. The phenomenon weakens the ball formation energy and the strength of ball neck region where it is called HAZ (Heat Affect Zone), portrayed in Figure 6. Therefore it is concluded that the wire bonding quality descend gradually when an EFO ward electrode wears.

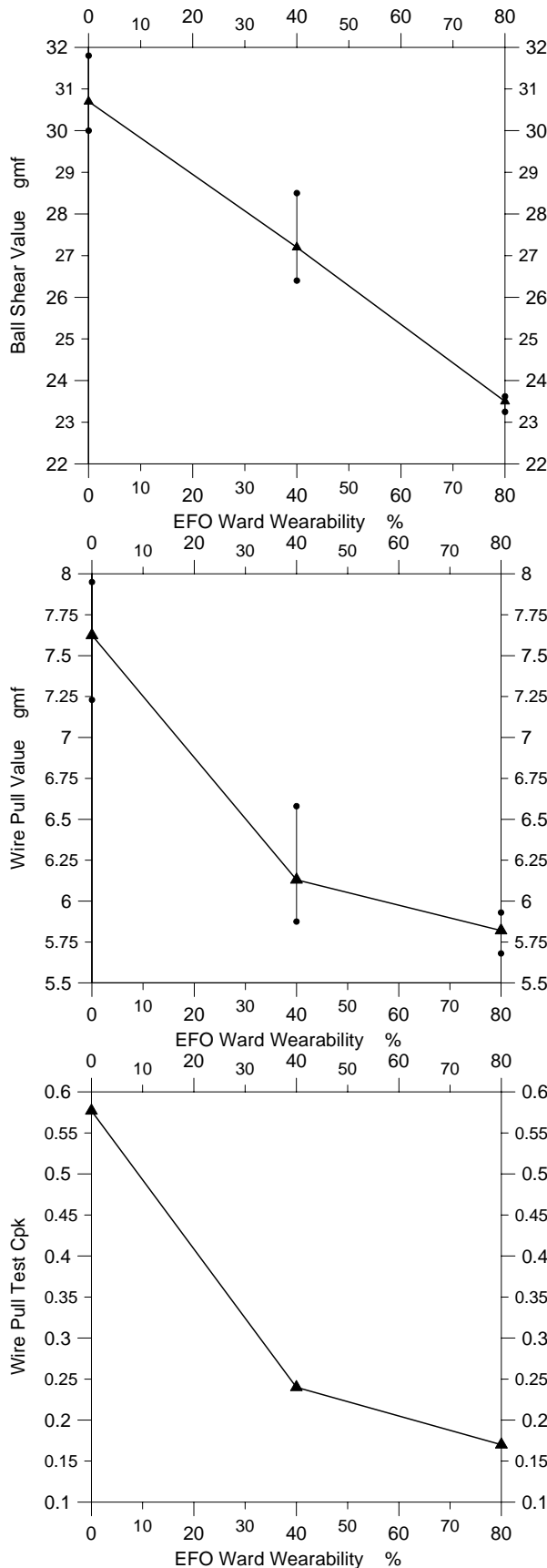


Figure 5. Ball shear, wire pull strength and its Cpk with different wear rate electrodes

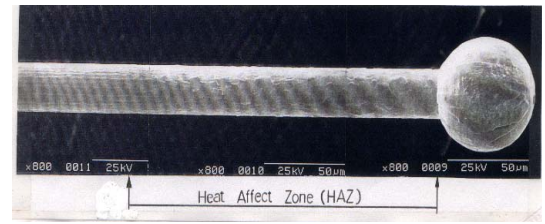


Figure 6. The SEM photograph of the HAZ of wire

Figure 7 shows the influences of the electrode surface pollution on the ball shear, wire pull strength and its Cpk. In the case of surface pollution electrode, the average of ball shear, wire pull and its Cpk are obviously lower than that of the surface cleanness electrode. The result indicates that the surface pollution electrode may transmit the EFO discharge combined with unexpected particles such as the oxide of Platinum to wire surface, and decrease the bonded ball homogeneity and weaken the strength of HAZ. As a result, the wire bonding quality decreases when the electrode surface was polluted.

Figure 8 displays the influences of different discharge gaps on the ball shear, wire pull strength and its Cpk. As increasing the discharge gap to 35 mil, the average of ball shear, wire pull and its Cpk decrease, and the average wire pull value decay to a lesser extent. The result indicates that the EFO discharge intensity correlates inversely to its transmit distance. The greater discharge gap has lesser discharge energy, which can weaken the strength of HAZ dramatically but effects ball shear strength slightly. Therefore the wire bonding quality descends as using the greater discharge gap.

4. Summary and Conclusion

In accordance with the results of EFO Ward Electrode Wear Experiment and Electrode Surface Pollution Experiment, wire bonding quality descends when EFO ward electrode wear and surface was polluted. As the discharge gap caused by electrode wear increasing, wire bonding quality decrease as well. The lowest wire pull and ball shear value have approached to actual production lines standards 6g and 25g respectively, and some even lower than specification. This is a warning sign behind the wire bonding process, which can reduce the capacity of process (Cpk) and affect the reliability of products, but there is less attention by process engineer. Therefore it is concluded if EFO ward electrode wear were controlled by adjusting discharge gap and

cleaning the surface of electrode regularly, wire bonding quality would not get worse.

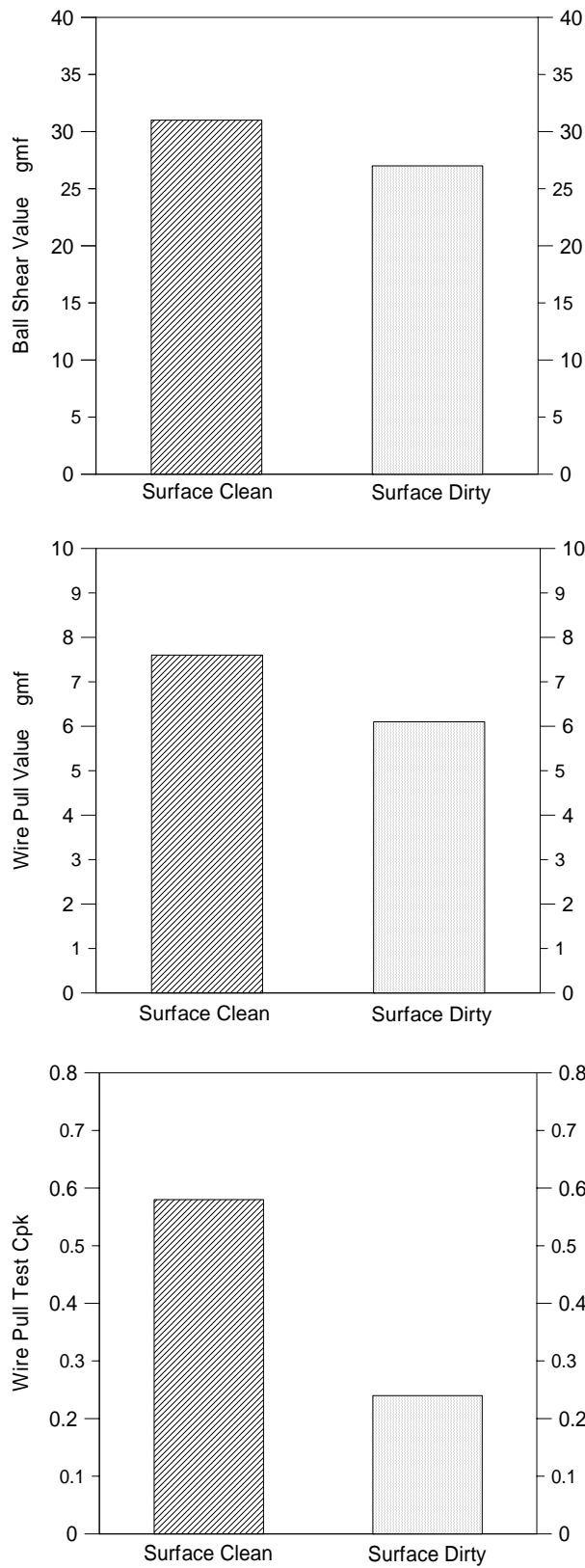


Figure 7. Variations of ball shear, wire pull strength and its Cpk with electrode surface conditions

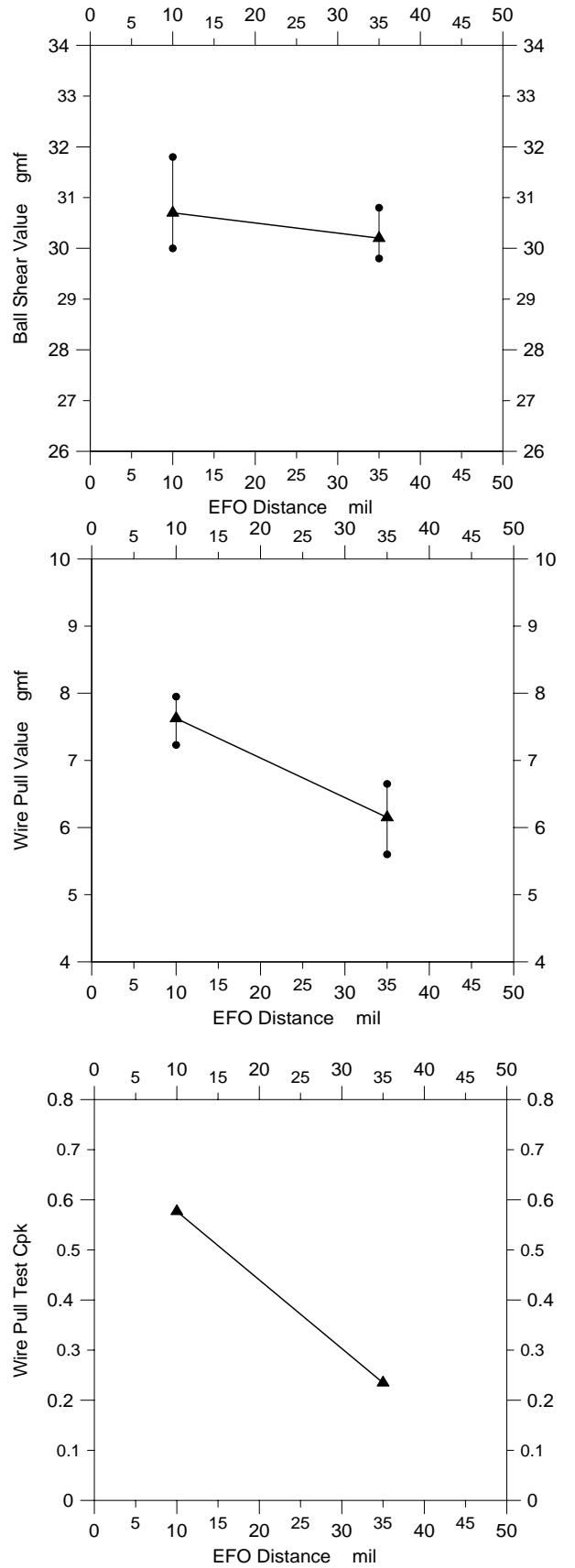


Figure 8. Variations of ball shear, wire pull strength and its Cpk with different discharge gaps

In order to eliminate the defect of wire bonding quality due to the EFO wand electrode wear, surface pollution, and gap variety which is caused by electrode wear, a multi-function detectable tool, showed in Figure 9, has been successfully designed. It can be not only to check up the wear and lifetime of electrode, but also to clean surface out of pollution. The solution was lately executed in actual production lines, and had been proved effectively.

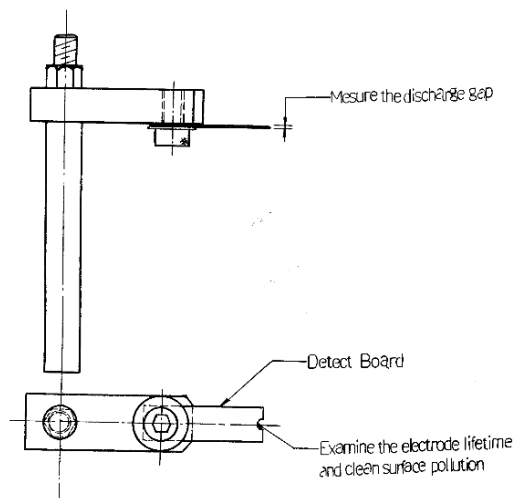


Figure 9. Schematic of the multi-function detectable tool

References

- [1] Huang, L. J., Jog, M. A., Cohan, I. M. and Ayyaswamy, P. S., "Effect of Polarity on Heat Transfer in the Ball Formation Process," *J. of Elec. Packaging Trans. ASME*, Vol.113, pp. 33-39 (1991).
- [2] Qin, W., Cohan, I. M. and Ayyaswamy, P. S., "Fixed Wand Electronic Flame-Off for Ball Formation in the Wire Bonding Process," *J. of Elec. Packaging Trans. ASME*, Vol. 116, pp. 212-219 (1994).
- [3] Chung, K. J., "EFO Wand Electrode Study~1st Report," Siliconware Corporation (1997).
- [4] Wire Bonding Station Operation Instruction, Siliconware Corporation, Hsinchu, Taiwan (1997).
- [5] Wire Bonder Operation Instruction, Siliconware Corporation, Hsinchu, Taiwan (1997).
- [6] Wire Bonder Maintenance Instruction, Siliconware Corporation, Hsinchu, Taiwan (1997).
- [7] K&S 1484 XQ Operation/Maintenance

Manu, K&S Industries Inc., PA, U.S.A. (1989).

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