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Tail Breaking Force in Thermosonic Wire Bonding with Novel Bonding Wires

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Abstract

Tail breaking forces (TBFs) are measured for various process conditions to understand phenomena such as short tail formation. TBFs obtained with several Cu wires are compared to find the most suitable Cu wire type that improves consistent tail formation. In situ online TBF measurement method is developed. The highest TBF obtained is 61.59 ± 9.10mN. The highest Cpk value obtained is 2.97 ± 0.33 when lower specification limit of 10 mN is assumed.

Introduction

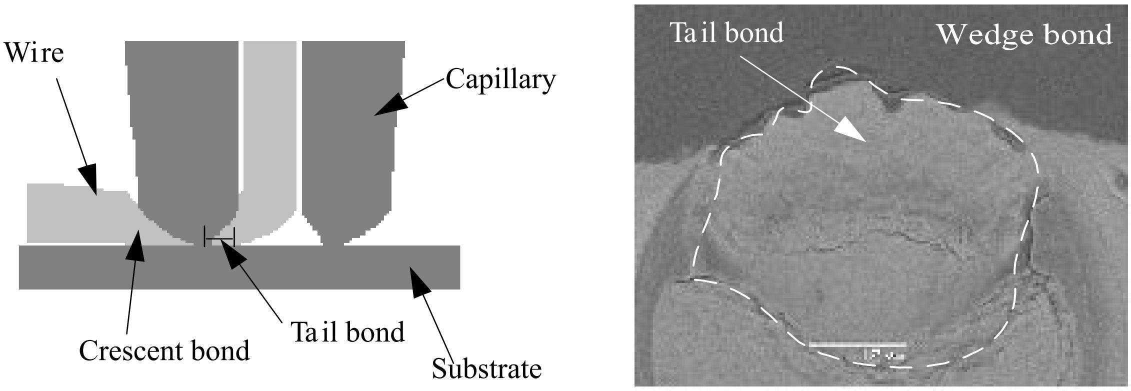
Demands on cost reduction, miniaturization, and fast switching speed have lead to replace Au wire with Cu wire [1] – [3]. Compared with Au wire, Cu wire is very stable in cost. Cu wire has a resistivity of 1.6 mΩ · cm, 33% lower than Au wire [1]. Excellent electrical conductivity and therefore low heat generation allow Cu wire to be used not only for power devices but also for fine pitch wire bonding applications. Furthermore, Cu wire shows ten times lower intermetallic growth rate than Au wire [4], so that mechanical and electrical problems caused by intermetallic compounds (IMC) can be eliminated during service. Despite these benefits, Cu wire bonding process can pose challenges especially for fine pitch wire bonding.

One of them is the premature termination of tail bond [5]. It is often called "short tail", "tail-lift off" or "EFO open". Figures 1 (a) and (b) show a schematic and back scattered electron (BSE) image of a tail bond, respectively. While performing the second bond the bonding wire is pinched by the capillary, separating the bond into a wedge bond and tail bond. Tail bonds should be strong enough to hold the wire until the clamp closes to tear the wire off because weak tail bond results in non uniform tail length and therefore non-uniform formation of free air balls. This can be one of the reasons reducing the yield of production. Sometimes, the wire is blown-out of the capillary as the tail breaks before the wire clamp closes. This causes a halt in production.

To understand the behavior of tail bond, an online TBF measurement method using proximity sensor is applied. TBFs are measured with various Cu wires.

Equipment and materials for TBF measurement

An ESEC WB 3100 wire bonder with proximity sensor was used for bonding process. PLCC 44 lead frames with Ag metallization were used. The thickness of Ag layer was 8µm. A set of several 99.99% purity 25µm Cu wires (MK Electron, LTD, Yongin, Korea) are used to characterize their TBF performance. The capillary used was a SPT SBNE-35BD-AZX-1/16-XL capillary with tip diameter and chamfer diameter of 100µm and 51µm, respectively.



(a) (b)

Fig. 1 Schematic (a) and back scattered electron image (b) of tail bond.

In-situ TBF measurement

A proximity sensor is attached on the clamp to measure real-time signals corresponding to the gap between clamp and horn. During the bonding process, the distance between proximity sensor and the horn changes. Normally the bonding force (BF) is evaluated from distance change.

Figure 2 shows this online force signal obtained during wire bonding. Impact force (IF) and BF are measured. For example, the bonding parameters for wedge bond were 1100mN, 500mN, 80%, 25ms for IF, BF, ultrasound (US), and bonding time (BT), respectively. After the wedge bonding, the tail break occurs. The signals during the tail breaking are indicated by “A” in Fig. 2.

The tail breaking portion of the signal is enlarged as shown in Fig. 3. The signal increases before the tail break as the wire tension increases. After it reaches a maximum value, the signal suddenly drops to zero indicating tail break. To obtain the TBF signal, two potions of the signals are averaged as indicated by (a) and (b). The difference between them is defined to be the TBF signal (S_{TBF}), 20mN in the example. Calibration is carried out using a microsensor. The TBF values are obtained in mN from the proximity sensor signal by multiplying a calibration factor, f_{TBF} = 3.5mN.

TBF comparison of Cu wires

Figures 4 (a) and (b) show the first and the third iteration results of Cu-G wire, respectively. Wires are bonded to only one direction, perpendicular to the ultrasonic direction (West). The Z-tear speed is set to a value, 2μm/s, low enough to resolve the tail breaking event. The bonding temperature (T) and the BT used were 220°C and 25ms, respectively. US, IF, and BF were varied to obtain maximum TBF.

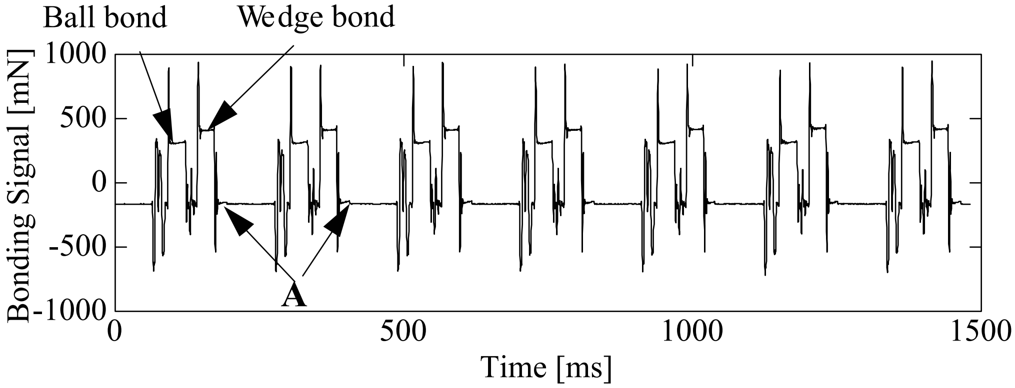


Fig. 2 Online force signal obtained from the proximity sensor during bonding five wires

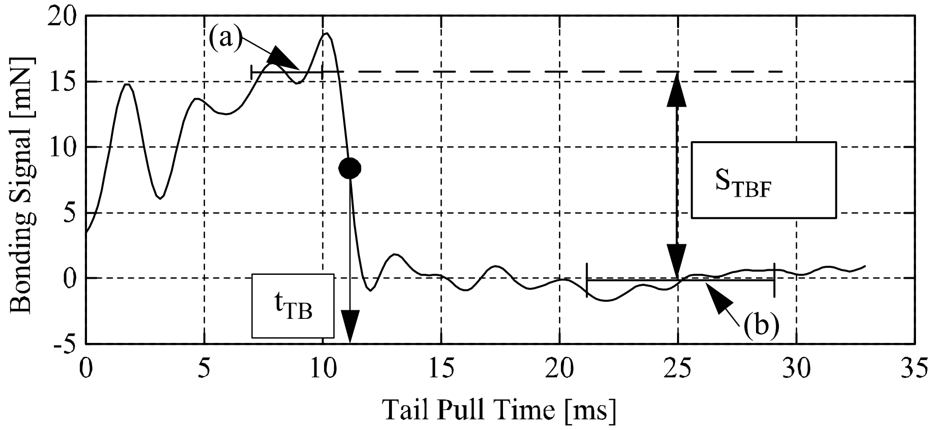
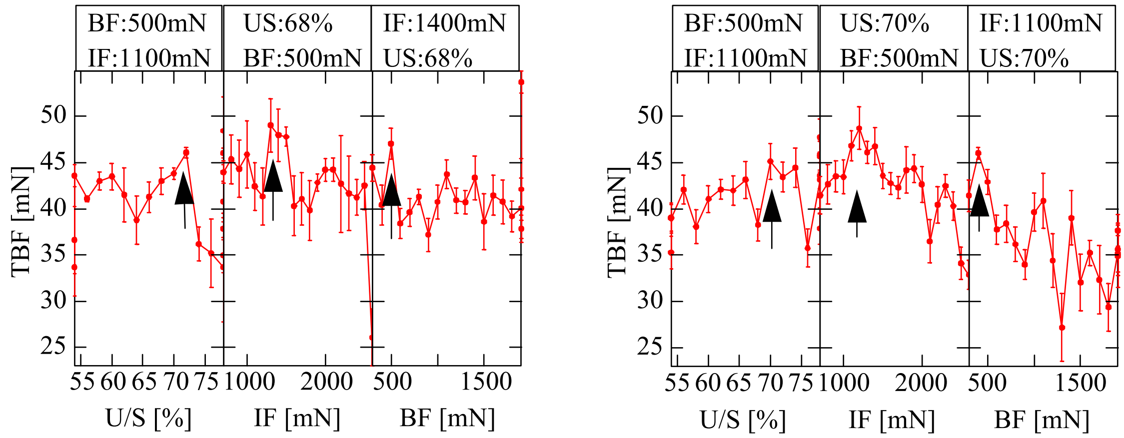


Fig. 3 Signal of A in Fig. 1.

The TBFs increase and decrease depending on the parameter combinations. At the first iteration process, maximum TBF is found at 72%, 1300mN, and 500mN of US, IF, and BF, respectively. At the third iteration process, maximum TBF is found at 70%, 1100mN, and 400mN of US, IF, and BF, respectively.



(a) (b)

Fig. 4 TBF iteration results of Cu-G wire. (a) 1st iteration and (b) 3rd iteration

These parameters are considered as center parameter as shown in Table 1. For reliable comparison of the TBF between Cu wires, 160 bonds with each wire were made with the center parameters for TBF evaluation. Table 1 shows the comparison results in terms of average TBF and cpk. Following formula is used for cpk calculation.

$$cpk = \frac{\overline{TBF} - LSL}{3\sigma} \tag{1}$$

where, TBF is average TBF, LSL is 10mN chosen as the lower specification limit, and σ is the TBF standard deviation.

For the calculation of the variation of cpk (σ_{cpk}), following equation is used [6].

$$\sigma_{Cpk} = z_{1-\alpha}\sqrt{\frac{1}{9n}+\frac{Cpk^{2}}{2(n-1)}} \qquad (2)$$

where, $Z_{1-\alpha}$ is 1.96 at 95% confidence, and n=160 is the number of measurements

Table 1 Cu wire comparison at the center parameter in terms of average TBF and Cpk

		Cu wire						
		A	B	C	D	E	F	G
Av. TBF (mN)		59.28	56.90	48.25	47.25	52.20	48.82	61.59
σ (mN)		6.82	5.03	5.50	6.72	5.96	5.61	9.10
Cpk		2.31±0.26	2.97±0.33	2.20±0.25	1.75±0.20	2.25±0.25	2.19±0.25	1.82±0.21
Center parameter	US (%)	78	74	68	74	72	68	70
	IF (mN)	1100	1000	1000	1000	900	800	1100
	BF (mN)	500	500	400	400	450	400	400

Bonded with center parameters, the Cu wires show average TBF and cpk higher than 47 mN and 1.75, respectively. The highest average TBF at the center parameter is obtained from wire G, 51.38 ± 7.59 mN. However, due to a high standard deviation (σ), this wire shows the lowest cpk. For example, Cu-G is less stable, in terms of TBF, than Cu-B. The average TBF and cpk of which are 56.90 ± 5.03mN and 2.97 ± 0.33, respectively.

Conclusion

The application of an In-situ real time TBF measurement method is reported. Following conclusions are obtained.

1. TBFs are successfully measured with the proximity sensor.
2. The TBF depends on the bonding parameter combinations. The highest TBFs are measured in the range of 68 ~ 78 %, 800 ~ 1100 mN, and 400 ~ 500 mN of US, IF, and BF, respectively.
3. TBF and Cpk depend on Cu wire types. The observed ranges of average TBF and Cpk are 47.25 ~ 61.59 mN and 2.21 ~ 3.69, respectively.

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