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Effect of Silicon Glue Staging Time on Pad Contamination and Au Ball Shear in MEMS Sensor Packaging

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Abstract. Wire bonding plays a critical role in the MEMS pressure sensor packaging process. The performance of wire bonding directly determines the functionality and service life of pressure sensors. During reliability qualification of safe-launch sample builds, wire-bond bump-ball lift was observed on the ASIC die of a stacked-die pressure sensor after 1000 cycles of temperature cycling. However, there are numerous factors affecting wire bond performance, including wire bond parameters, bond pad contamination, plasma cleaning effectiveness and process variation. Accordingly, this study investigated the root cause of this issue. The DOE results indicated that silicon glue staging time is a key factor affecting pad contamination. This contamination impaired the interfacial integrity between the bump ball and bond pad, as reflected in low ball shear strength, and ultimately led to ball lift after temperature cycling testing. Ball shear strength tests with staging time DOE units showed that from a staging time of 3 hours to 12 hours, the average ball shear strength decreased from 31.30 g to 27.22 g. Optimizing wire bond parameters can significantly improve ball shear strength and reduce the effect of pad contamination associated with silicon glue staging time. With the improved wire-bond parameters, the average ball shear strength was 31.06 g after 12 hours of staging. Furthermore, improvement actions for products with similar structures are proposed and discussed based on the experimental results.

Keywords: Stacked Die, Wire Bonding, Ball Shear, Silicon Glue Staging Time, Wire Bonding Parameters

1. Introduction

The pressure sensor consists of an ASIC die and a MEMS die in a stacked structure. The ASIC die is at the bottom, and the MEMS die is stacked on top of it. Au wire is used to interconnect the ASIC die bond pads to both lead frame bond pads and MEMS bond pads. Both wire bonding steps use the BSOB (Bond Stitch On Ball) method, and the bump balls are always formed on the ASIC die. In total, the two wire bonding steps form 8 bump balls on ASIC die. 3 bump balls are bonded in the first wire bond step and 5 bump balls are bonded in the second wire bond step. The surface material of all bump ball pads on the ASIC die is Pd.

In order to verify the reliability of the new product, samples from four different safe launch sample build lots were selected for 1000 cycles of temperature cycling, with 77 units per lot.

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Occasional instances of ASIC ball lift were detected in the first lot.

Vath, J.C. et al. demonstrated that wire bond performance can be evaluated by measuring ball shear strength. Low ball shear strength between bump ball and bond pad can lead to ball lift during reliability testing [1]. Knotter M D and Yen L H reported that bond pad contamination leads to poor bondability and reduced ball shear strength [2, 3]. Yen L H et al. resolved it by improving the bond pad structure. However, this solution is not applicable to this article because the bond pad structure has been finalized and cannot be modified. M. K verified that epoxy can contaminate bond pad surfaces through thermal outgassing during the epoxy curing process [4]. Research by Maleki P et al. and He L and Liu H T found that ionic contaminants such as Cl^- and S^2 species can corrode the interfacial intermetallic compound at the bond interface, leading to reduced ball shear strength [5, 6]. Li X et al. and another study reported that using plasma can remove residual contamination on bond pads [7, 8]. KUNG T A et al. showed that EDX can identify the elements remaining on the bond pad surface [9].

At present, most failure analyses of wire bonds focus on single-die packages with conventional bonding processes. In addition, Al remains the dominant bond pad metallization in the industry, since both Al and Au possess a face-centered cubic (FCC) crystal structure, which is favorable for intermetallic compound (IMC) formation and bond quality [10]. The product investigated in this article, however, is one of the few products that use Pd bond pads bonded with Au wire in a two-step wire bonding process. Furthermore, the die bond material used here is silicon glue which is different from normal silver epoxy. Most importantly, both wire bonding processes use the same materials, and both the first and second wire bonding steps include a plasma cleaning step to remove contamination on die bond pads to enhance the performance of wire bond. However, only the second wire bonding step has this issue.

The purpose of this article is to investigate the root cause of low ball shear strength by studying the wire bond parameters and packaging process of stacked die products. The research results are expected to provide valuable insights into the development and process control of other stacked die packages that use silicon glue for die bond adhesives.

2. Materials and methods

2.1. Materials

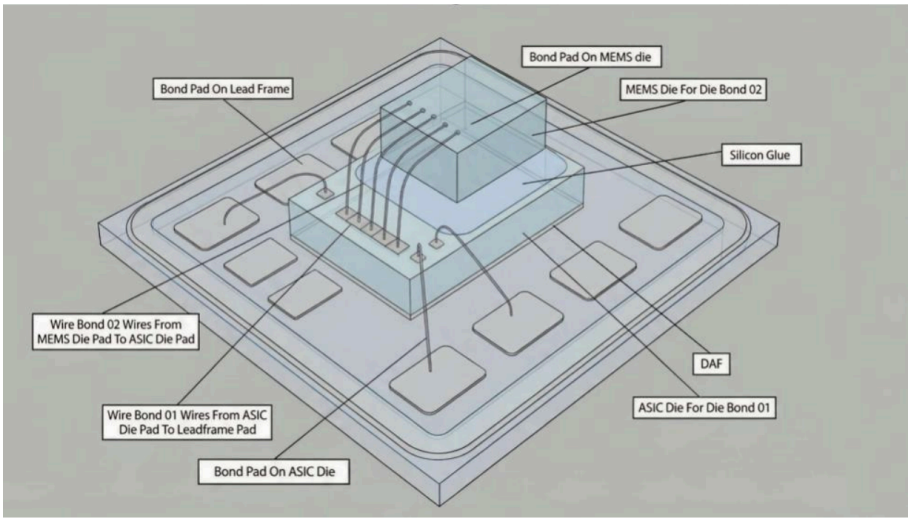

Figure 1. Pressure sensor materials and structure

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The materials used in the pressure sensor packaging process include a lead frame, two stacked dies, namely an ASIC die and a MEMS die, and die attach film used to bond the ASIC die to the lead frame. Silicon glue is used to bond the MEMS die onto the ASIC die, and Au wire is used to connect die bond pads and lead frame bond pads, as shown in Figure 1.

2.2. Packaging process

The front-end packaging process for the stacked-die pressure sensor is divided into two parts. Each part consists of Die Bond, Post Bond Cure, Plasma Clean and Wire Bond. Therefore, the complete front-end packaging process has 8 stations. The first station is Die Bond01, which is a station of bonding an ASIC with die attach film onto the die paddle of the lead frame. Glue Cure01 is a station of curing die attach film until fully hardened. WB01 Plasma Clean is a station of cleaning ASIC die and lead frame bond pad surfaces to enhance WB01 performance. Wire Bond01 is a station of connecting ASIC die and lead frame with Au wire. Die Bond02 is a station of bonding a MEMS die onto the ASIC die surface. Die Bond02 requires dispensing silicon glue onto the ASIC surface to help bond the MEMS die. Glue Cure02 is a station of curing silicon glue until fully hardened. WB02 Plasma Clean is a station of cleaning ASIC die and MEMS die bond pad surfaces to enhance WB02 performance. Wire Bond02 is a station of connecting MEMS die and ASIC die with Au wire. The packaging process flow is illustrated in Figure 2.

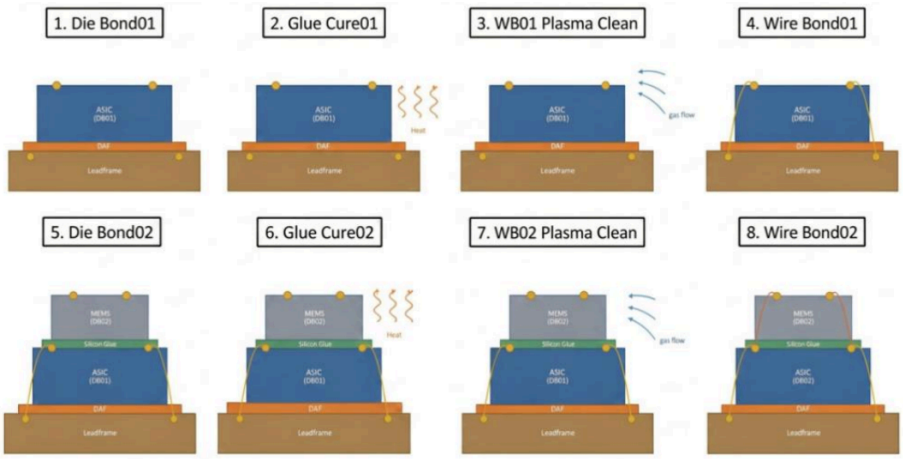

Figure 2. Packaging process flow illustration

2.3. Preliminary wire bond parameter screening

This pressure sensor has a total of eight Au bump balls formed on the ASIC bond pads: three at Wire Bond01 and five at Wire Bond02. All bump balls use Au wire, and the bond pad surface material is the same, but only WB02 bump balls have a ball lift issue after temperature cycling testing. Based on the material analysis, it is suspected that different bump ball parameters between the Wire Bond01 and the Wire Bond02 led to different results. After comparing the bump ball parameters between the Wire Bond01 and the Wire Bond02, it was found that the Wire Bond01 used high force to form bump balls, while the Wire Bond02 used low force combined with scrub to form bump balls. Samples were built with the Wire Bond01 parameters and the Wire Bond02 parameters at the same time, with 25 bump balls for each parameter set. For each parameter set, 25 bump balls from five units were tested, with five balls sheared per unit. Ball shear strength measurements were used to

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identify which parameters performed better. The ball shear strength measurement method is shown in Figure 3.

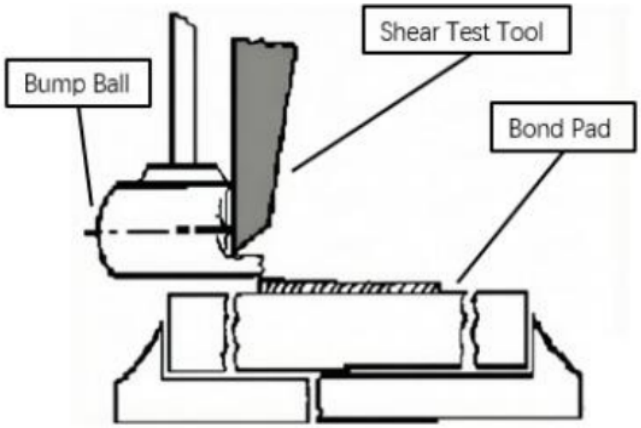

Figure 3. Ball shear strength measurement method

The ball shear results showed that the Wire Bond01 parameters had better performance than the Wire Bond02 parameters in both ball shear strength and process stability. Table 1 compares the ball shear strength between the WB01 and WB02 parameters.

Table 1. Comparison between WB01 and WB02 performance

Parameters	Max (g)	Min (g)	Mean (g)	SD (g)	Cpk
Wire Bond01	39.47	32.41	35.53	1.95	2.83
Wire Bond02	36.31	29.21	32.87	2.12	2.18

2.4. Staging time experimental design

Since ball lift was detected only in the first lot, the process mapping of four safe launch sample build lots was checked again. It was found that 4 lots used one die bond machine and due to oven capacity, the first lot was held until all 4 lots completed die bonding, after which all four lots were released to the glue curing station at the same time. Therefore, the first lot had the longest staging time between die bonding and glue curing. In addition, the die attach film used in Die bond01 is initially in a solid state, but the silicon glue used in Die bond02 is initially a highly viscous liquid. Therefore, it is preliminarily suspected that a longer staging time will cause variation. In order to verify this hypothesis, a DOE was proposed with 3 hours, 4 hours, 5 hours and 12 hours staging time between Die Bond02 and Glue Cure02.

2.5. EDX and ball shear characterization

After staging, Glue Cure02, and WB02 plasma cleaning, EDX was used to determine whether the ASIC die bond pad surface was affected. Raw dies and samples from the four staging-time conditions were examined. For each condition, EDX spectra were collected at three Wire Bond02 bond-pad positions, and one position on the silicon glue was analyzed to identify the glue composition. Bump ball shear tests were also performed on the staging time DOE units. For each

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staging-time condition, 15 units were tested, with five bump balls sheared per unit (n = 75). The EDX measurement positions are shown in Figure 4.

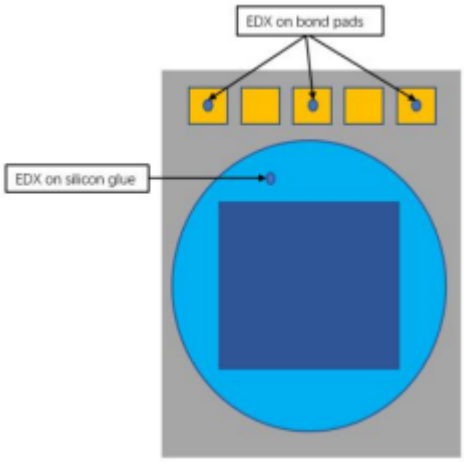

Figure 4. EDX position

3. Results and discussion

3.1. EDX analysis of ASIC bond pad contamination

EDX results for the raw ASIC die bond pad surface showed the following elements: 11.61 wt% O element, 3.55 wt% C element and 84.84 wt% Pd element. EDX results for the silicon glue showed the following elements: 45.74 wt% O element, 34.55 wt% C element, and 19.71 wt% Si element.

EDX analysis of the staging time DOE showed that Si was detected on the ASIC die bond pad after 3 hours of staging, at 1.16 wt%; at the same time, the C and O elements increased by about 2 wt%. After 4 hours staging time, O element reached 17.2 wt% and C element increased to 6 wt%, while the Si content remained at approximately 1.1 wt%. After 5 hours staging time, C, O and Si elements reached 6.7 wt%, 19.45 wt% and 1.12 wt% respectively. There was no significant difference in the elements weight percentages observed between staging times of 12 and 5 hours. Table 2 presents the EDX results of staging time DOE.

Table 2. EDX results for the staging-time DOE

Condition	O wt% Average	C wt% Average	Si wt% Average	Pd wt% Average
Silicon Glue	45.74%	34.55%	19.71%	/
Raw Die	11.61%	3.55%	0.00%	84.84%
3 Hours Staging Time	14.18%	5.46%	1.16%	79.20%
4 Hours Staging Time	17.20%	6.00%	1.10%	75.70%
5 Hours Staging Time	19.45%	6.70%	1.12%	72.73%
12 Hours Staging Time	19.39%	6.67%	1.16%	72.78%

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3.2. Effect of silicon glue staging time on ball shear strength

Wire Bond02 bump ball shear tests on staging time DOE units demonstrated that bump ball shear strength decreased monotonically with longer staging time. The average bump ball shear strength decreased from 31.3 g to 27.22 g. Correspondingly, Cpk decreased from 2.32 to 1.31. Both indicate that longer staging time leads to worse Wire Bond02 performance and process stability. Wire Bond02 ball shear strength with staging time results are presented in Figure 5.

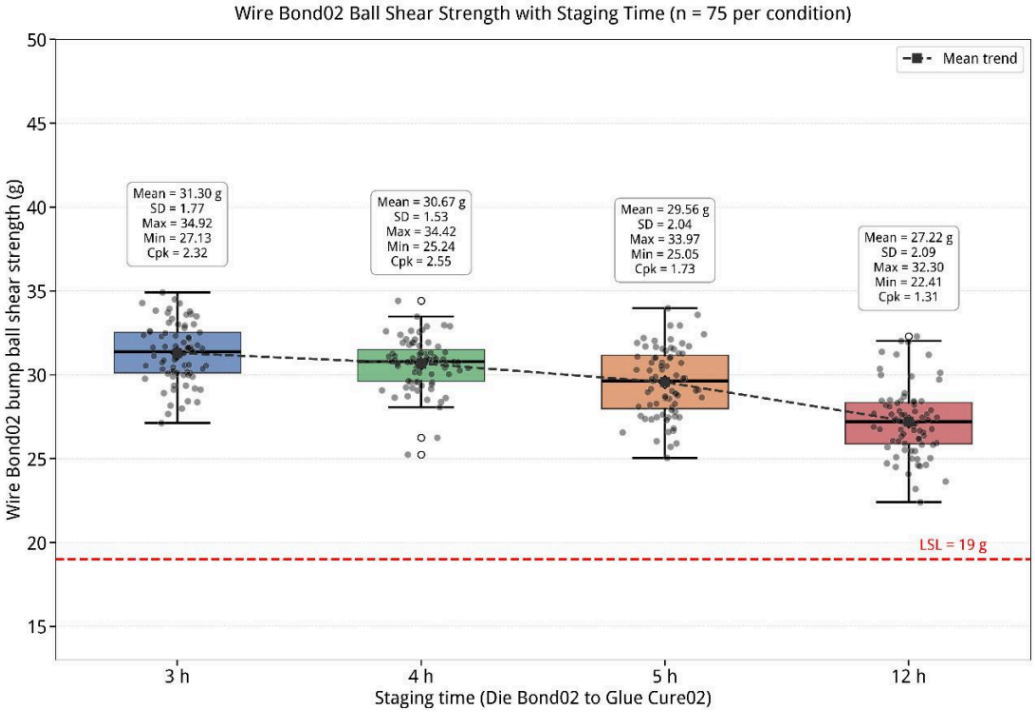

Figure 5. Wire Bond02 ball shear strength with staging time

3.3. Improved wire bond parameter screening

As presented in Table 1, Wire Bond01 parameters demonstrated better performance and process stability. However, Wire Bond02 parameters cannot fully compensate for the influence of staging time based on staging time DOE results. Therefore, it is proposed to optimize parameters of Wire Bond02 and verify the feasibility of the improved parameters through an additional ball shear test with staging time DOE units. For each staging-time condition, 15 units were tested, with five bump balls sheared per unit (n = 75).

The improved parameters combined the advantages of the original Wire Bond01 and Wire Bond02 parameters, using a combination of scrub and high force to form bump balls. Experimental results showed that the improved parameters performed better than the original Wire Bond01 and Wire Bond02 parameters. Although ball shear strength exhibited a gradual decrease from 3 hours staging time to 12 hours staging time, the average value and Cpk both indicated that the improved parameters had better performance and process stability to accommodate staging time variation. Ball shear strength results for the improved parameters at different staging times are shown in Figure 6.

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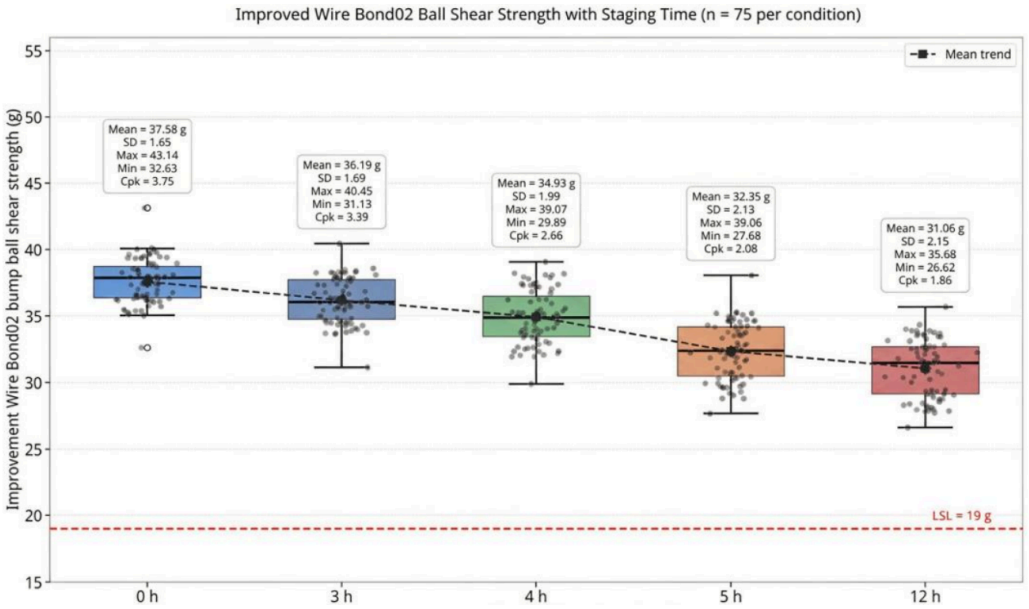

Figure 6. Effect of staging time on ball shear strength using the improved WB02 parameters

3.4. General discussion

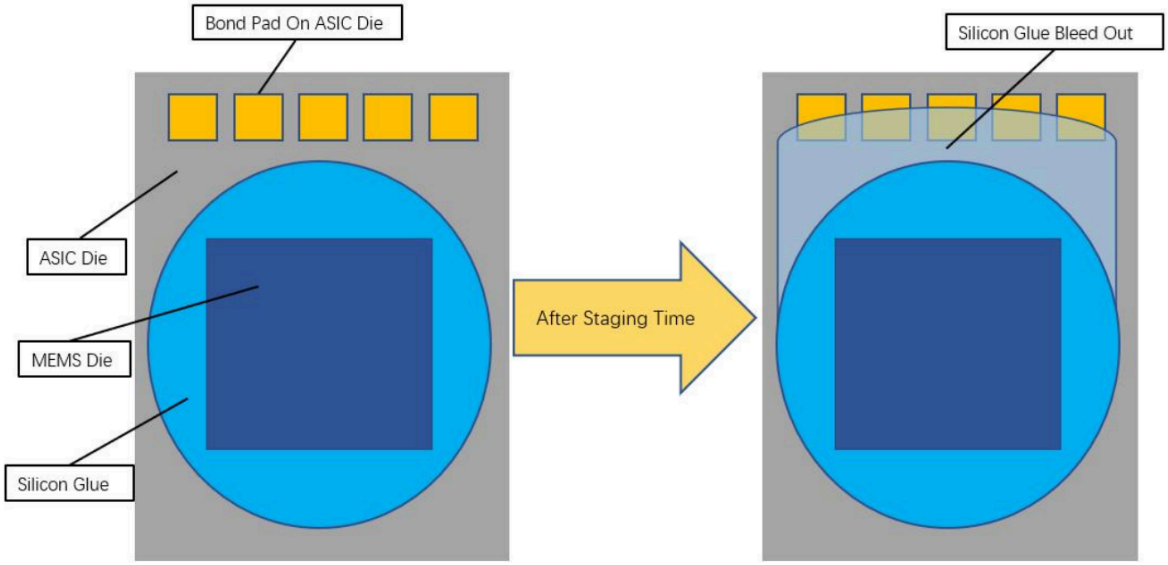

Figure 7. Silicon glue bleed-out illustration

Based on the EDX analysis and ball shear strength test results, it can be concluded that long staging time leads to residues of glue components on the ASIC die bond pad. Longer staging time leads to lower ball shear strength and worse process stability of Wire Bond02. The root cause is attributed to the bleed-out of the high viscosity liquid silicon glue used in Die Bond02 during long staging time. The migrated silicon glue was cured during the Glue Cure02 station, and formed a thin contamination layer on the bond pad that impacted Wire Bond02 performance. Since the plasma clean station uses an Ar and H_2 combination plasma gas, which mainly removes metal oxides and may be insufficient to remove silicon glue residues [11, 12], the contamination layer still remains on the bond pad surface after plasma clean, continuing to impair the Wire Bond02 station. Based on the

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ball shear test results for the improved Wire Bond02 parameters, the improved parameters can mitigate the effects of bond pad contamination after 12 hours of staging. A silicon glue bleed-out illustration is presented in Figure 7.

4. Conclusions

Based on the EDX analysis, staging time DOE, and ball shear test results, longer staging time between Die Bond02 and Glue Cure02 was associated with bond pad contamination and reduced ball shear strength in this pressure sensor product. The average shear strength with the original WB02 parameters decreased from 31.3 g at 3 hours to 27.22 g at 12 hours. To address this issue, two corrective actions are proposed. The first action is limiting the staging time between Die Bond02 and Glue Cure02 to a maximum of 4 hours. Considering that each lot needs approximately 2 h to process the Die Bond02 step, and Wire Bond02 performance declined by the 5 h condition, a 4 h limit provides a practical process-control point. The second action is improving the Wire Bond02 parameters by combining scrub with a high bonding force. The improved parameters produced higher ball shear strength at the corresponding staging times, suggesting that parameter optimization can help reduce the effects of pad contamination.

References

[1] Vath, J. C., Srikanth, N., & Murali, S. (2004). An evaluation of gold and copper wire bonds on shear and pull testing. *Journal of Electronic Packaging, 128*(3), 192–201. DOI: 10.1115/1.2229214.

[2] Yen, L. H., & Lai, I. F. (2025). Solving bump bonding issues with 2.0 mil copper wire: A study on FSM integration and workability improvements. *Microelectronics Reliability, 167*, 115628–115628. DOI: 10.1016/J.MICROREL.2025.115628.

[3] Knotter, M. D., Rink, A. I., Claassen, A. W., et al. (2011). Bond pad surface quality for reliable wire bonding. *Microelectronic Engineering, 88*(12), 3452–3458. DOI: 10.1016/j.mee.2011.01.075.

[4] M., K., T., T., & H., F. (1987). Aluminum bond pad contamination by thermal outgassing of organic material from silver-filled epoxy adhesives. *IEEE Transactions on Components, Hybrids, and Manufacturing Technology, 10*(4), 586–592. DOI: 10.1109/tchmt.1987.1134781.

[5] Maleki, P., Safar, A. A., Marques, A. E., et al. (2026). Failure analysis of interconnections and bi-material interfaces in microelectronic packages and semiconductors: A review. *Engineering Failure Analysis, 197*(PB), 111242–111242. DOI: 10.1016/J.ENGFAILANAL.2026.111242.

[6] He, L., & Liu, H. T. (2017). Failure mechanisms and analysis of wire bonding. *Microprocessors, 38*(6), 17–20. (in Chinese)

[7] Patents; researchers submit patent application, "Wire bond cleaning method and wire bonding recovery process", for approval (USPTO 20170110437). *Chemicals & Chemistry, 5910*.

[8] Li, X., Du, Y. H., Gao, L. Y., et al. (2024). Effect of plasma cleaning on the surface condition and mechanical properties of Cu/Al wire-bonded joints. *Transactions of the China Welding Institution, 45*(12), 14–19. (in Chinese)

[9] Kung, T. A., Bang, S. H., & Bang, S. H. (2006). Irregular characteristics of bond interface formation in ultrasonic wire wedge bonding. *Journal of Materials Science & Technology*(4), 483–486.

[10] Gan, L. C., Classe, et al. (2014). Effects of bonding wires and epoxy molding compound on gold and copper ball bonds intermetallic growth kinetics in electronic packaging. *Journal of Electronic Materials, 43*(4), 1017–1025. DOI: 10.1007/s11664-014-3011-y.

[11] Olander, B., Wirsén, A., & Albertsson, A. (2003). Silicone elastomers with controlled surface composition using argon or hydrogen plasma treatment. *Journal of Applied Polymer Science, 90*(5), 1378–1383. DOI: 10.1002/app.12835.

[12] Hino, T., Igarashi, Y., Ymauchi, Y., et al. (2008). Surface wettability of silicon rubber after irradiation with a glow discharge plasma. *Vacuum, 83*(3), 506–509. DOI: 10.1016/j.vacuum.2008.04.015.