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Bond Pad Probe Marks Effect on Intermetallic Coverage

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Authors' contributions

This work was carried out in collaboration amongst the authors. All authors read, reviewed, and approved the final manuscript.

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ABSTRACT

The paper presents a study on the effect of semiconductor die's bond pad probe marks on the interface between the wire and the bond pad. The probe marks are quantified in terms of percentage area in the bond pad, while the interface strength between the wire of Gold material to the Aluminum bond pad is measured through the intermetallic coverage (IMC). Actual evaluation showed that the size of the probe marks has significant impact on the bond pad area, especially on IMC. Validations were made comparing the IMC and shear strength performance of the wire ball bonded on the worst-case probe marks and on the standard probe marks. The learnings on this study could be used on future works with similar requirement.

Keywords: Ball bond; ball shear; bond pad; IMC; probe mark; wirebond.

1. INTRODUCTION

The intermetallic formation between bondwire (or simply wire) of either Gold (Au), Silver (Ag) or Copper (Cu) material to the Aluminum (Al) bond pad is one of the critical factors in measuring the reliability and integrity of wirebonding [1-4]. In automotive application,

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the wire bond pad IMC is anticipated to withstand thermal cycling requirement greater than 2000 cycles, as part of a more stringent test to measure the product robustness. Note that with new and continuing technology trends and state-of-the-art platforms, challenges and varying requirements in semiconductor packaging are inevitable [5-8].

For quad-flat no-lead (QFN) leadframe package manufacturing, the current product performance is between 500-1000 cycles only, which creates challenges for the transition of QFN packages for automotive application. Early delamination between intermetallic layers of wire to bond pad, degrades usually occurs between 1000-1500 cycles. Shown in Fig. 1 is the defect signature of poor IMC of Au wire on Al bond pad encountered on QFN device after 1000 cycles. The defect signature eventually would cause delamination or non-sticking of the wire to the bond pad.

The IMC measurement for the affected interconnection is measured between 65-70%. The remaining 30% is observed with poor interconnection on the Al bond pad and identified to be the main cause for the early breakdown in the Au wire to Al bond pad interfaces.

This study discusses the improvement on the intermetallic through optimizing and identifying an acceptable probe mark size on the bond pad. Establishing the product and manufacturing controls directly increases the intermetallic connection which provides more reliable performance for the product.

2. METHODS AND RESULTS

Analysis for the defect signature identified probe mark size as one of the main root-cause for encountering low IMC growth for wire bond pad connection. From the result, there is no IMC formation on the middle portion of the ball bond as seen in Fig. 2 after chemical etching that is proportional to the location of the probe mark in the bond pad.

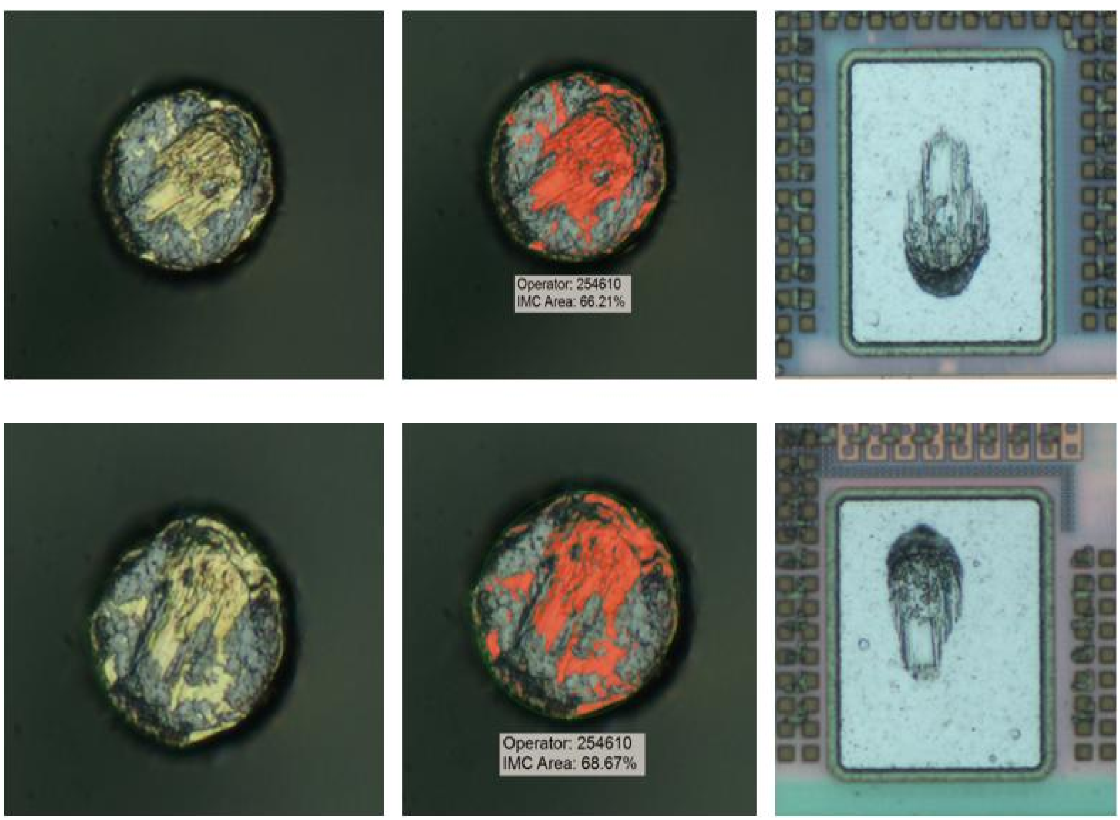

Fig. 1. IMC measurement of ball bond and snapshot of delamination on bond pad

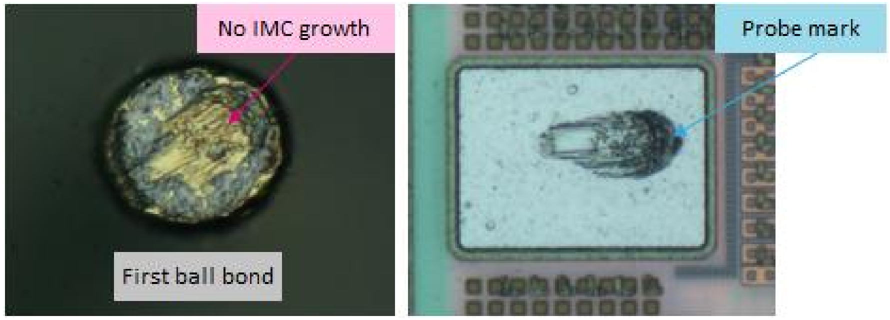

Fig. 2. Defect signature

The worst-case probe mark is measured and compared to the standard probe marking size. Fig. 3 shows the comparison in area between the sizes of standard and worst-case probe markings.

The standard measurement of probe mark versus the size of the bond pad is approximately between 4-7% while worst-case probe marking is measured around 18-21%. Statistical analysis through analysis of variance reveals the two measurement are significantly different. Samples of actual probe marks in comparison are given in Figs. 4-5.

A ball shear test is performed to measure the shear strength of the bonded wire. Fig. 6 shows the statistical analysis of bond pad probe mark versus the ball shear. The non-formation of IMC impacts the strength of the material to resist delamination during thermal cycling procedure. in this study, the ball shear is one applicable test to measure the significance of the intermetallic between worst-case and standard probe marking.

Comparing the two probe mark size shows a significant difference in terms of ball shear reading. The R-squared reading in this test is measured greater than 60% between the two samples signifying that there is a significant decrease in ball shear for bigger probe marks. Visually, through the All Pairs Tukey-Kramer test, the two circles are not intersecting (they are far apart) indicating a significant difference between the worst-case probe mark and standard probe mark in terms of the ball shear performance. Standard probe mark results to better ball shear strength. Moreover, the IMC formation for standard probe mark resulted to better measurement as exhibited in Fig. 7. The IMC growth is even throughout the ball, which also has a positive result in terms of ball shear.

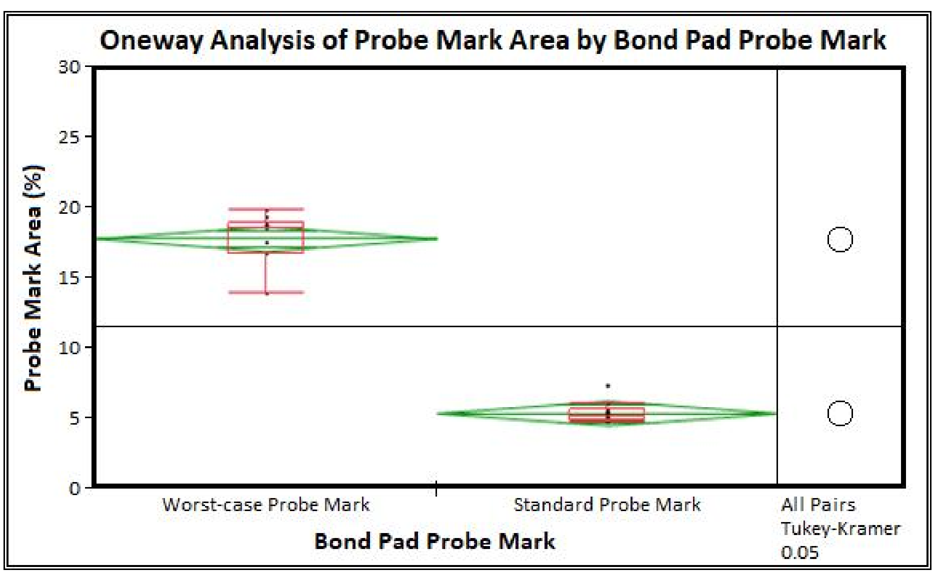

Fig. 3. Probe mark comparison

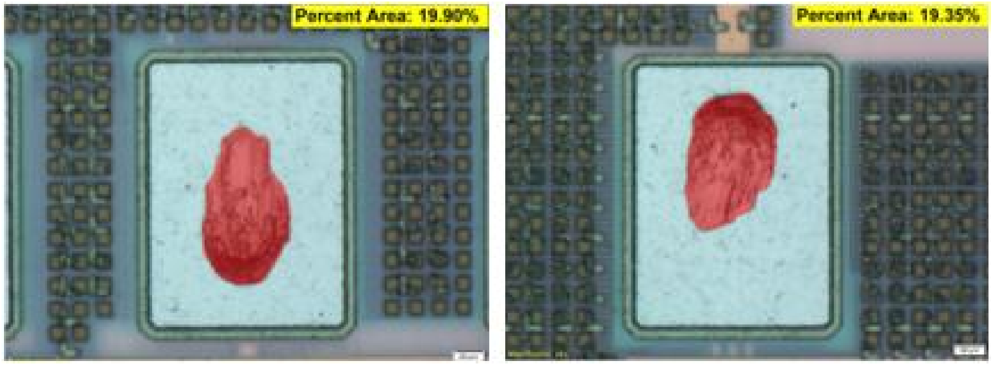

Fig. 4. Worst-case probe marks

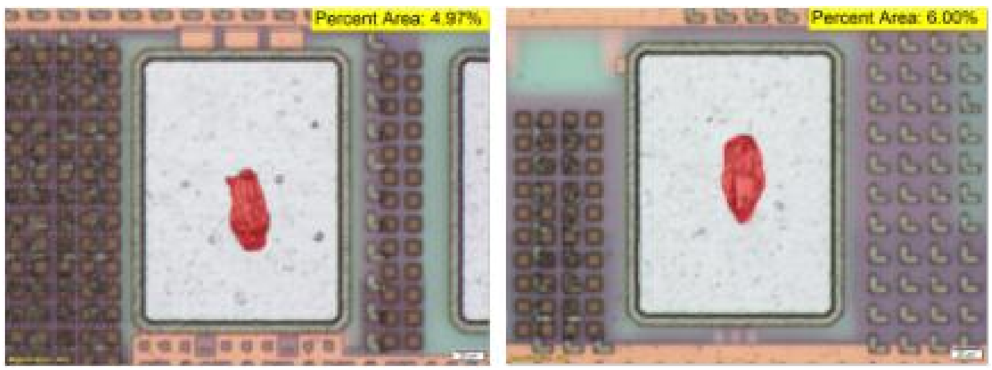

Fig. 5. Standard probe marks

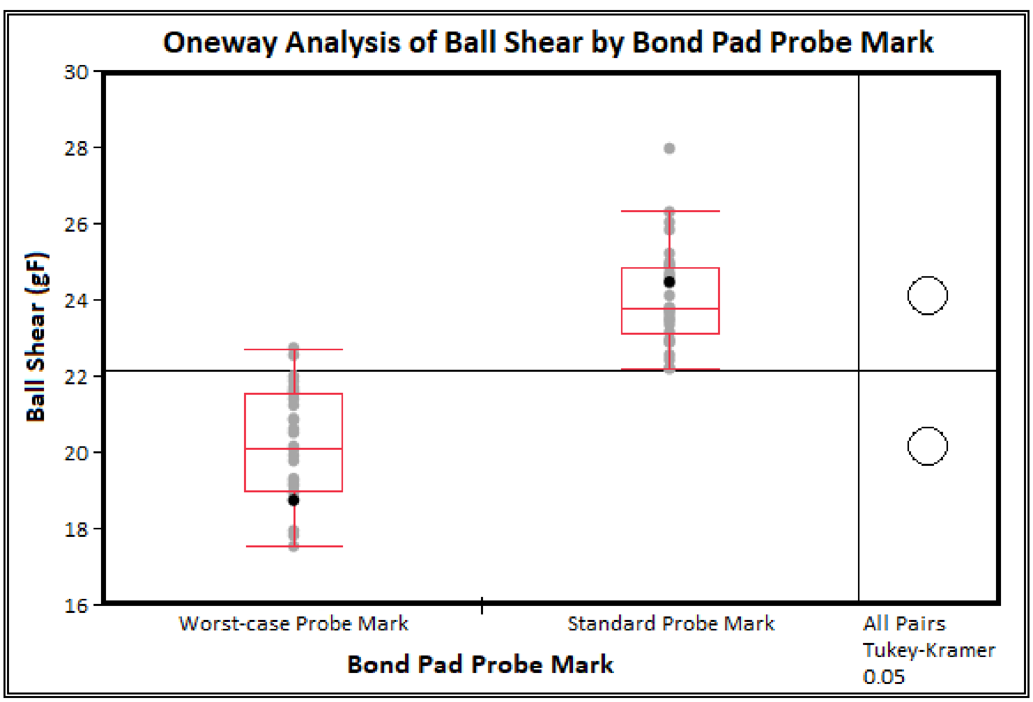

Fig. 6. Ball shear result

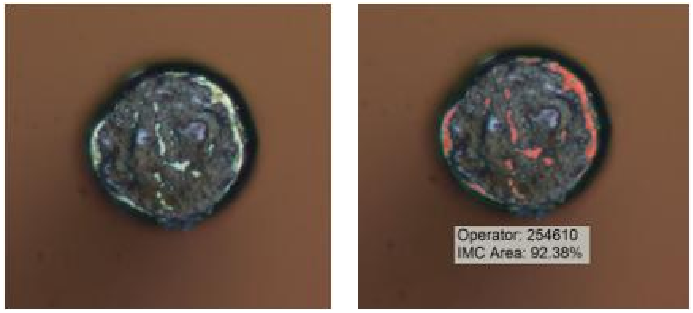

Fig. 7. IMC of standard probe mark

3. CONCLUSION AND RECOMMENDATIONS

The study showed that the size of the probe marks has significant impact on the IMC and ball shear performance of the Au wire. This is validated by comparing the worst-case probe mark versus the standard probe mark in terms of the ball shear test. Through the evaluation, the acceptable probe mark area is recommended to less than 10% of the bond pad area, with the standard probe marks having just 4-7% area of the bond pad.

For succeeding works and studies, the learnings presented in this paper could be used as a reference for probe marks and IMC during wirebond process. A comparison of this study should also be made with other works in the same field. Study of material properties on the delamination phenomenon could also be explored. Discussions and learnings shared in [1-4,9-11] are helpful for wirebond process robustness and improvement.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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